

The AMSAT[®] Journal

ARISSat-1

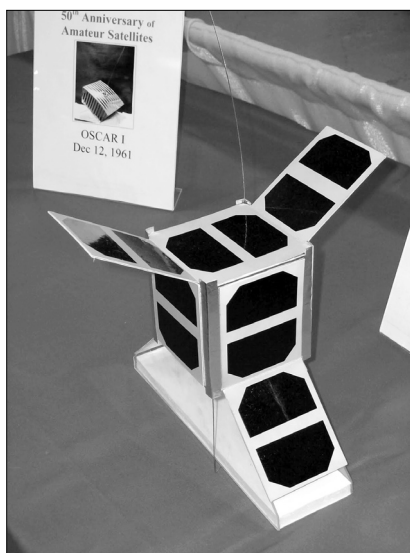


Editor-in-Chief:
Ed Long, WA4SWJ

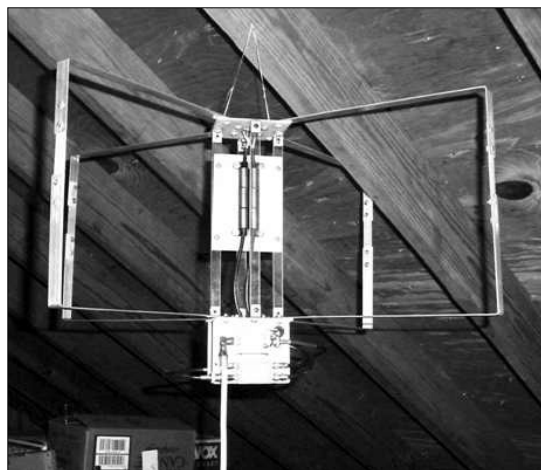
Assistant Editor:
Bill Hook, W3QBC

Volume 34, Number 3

July/August 2011



Project Fox Update



Need a Stealth Antenna?

in this issue

AMSAT Announcements2

Apogee View3
by Barry Baines • WD4ASW

Working the Japanese Amateur4
Radio Satellites
by Keith Baker • KB1SF/VA3KSF

AMSAT Fox CubeSat Program6
Update
by Anthony Monteiro • AA2TX

Crossed Moxon Turnstile.....9
for Satellite Users
by John M. Franke • WA4WDL

AMSAT BoD Telecon Meeting.....12
1 March 2011
by Alan Biddle • WA4SCA

Twins! A Backpack-Portable.....14
Full Duplex Satellite Station
with Dual FT-817ND's
by David A. Palmer • KB5WIA

ARISS = Education17
by Rosalie White • K1STO

Memories of Early Satellite.....19
Work
by David Kruh • WB2HTO

Educated Paradigm Shift for25
AMSAT to Support Subsidized
Launch Opportunities
by Mark Spencer • WA8SME

OSCAR-129
50 Years of History

Periodicals
POSTAGE PAID
At Silver Spring, MD
and at additional
mailing offices

AMSAT-NA
850 Silgo Avenue, Suite 600
Silver Spring, MD 20910-4730

How You Can Help Build New and Exciting Satellites

Donate to the President's Club

Gold, Silver, Bronze and Core levels are available to match your ability to participate.

Cash Gifts

Visa, or MasterCard or checks are accepted. And, you can specify how your contribution is to be used.

Gift of Life Insurance

US taxpayers may be able to receive a significant income tax deduction by making The Radio Amateur Satellite Corporation the owner and beneficiary of life insurance policies.

Gift of Stocks or other Securities

US taxpayers should be able to avoid capital gains taxes on appreciated securities and receive a deduction for their fair market value.

Bequest

A codicil in your will, naming The Radio Amateur Satellite Corporation as a beneficiary will help insure the continuance of the Amateur Radio Satellite program.

Call the AMSAT-NA office at 301-589-6062 for questions on any or all of these ways you can help build new and exciting satellites.

Support AMSAT-NA

AMSAT Announcements

OSCAR 1 Prototype Will Be Operating at the 2011 Symposium

The AMSAT 2011 AMSAT Space Symposium will be held on Friday, November 4th through Sunday, November 6th at the Windham Hotel in San Jose, California. This year's Symposium coincides the celebration of the 50th anniversary of OSCAR 1.

Symposium Banquet Speaker and OSCAR 1 developer Lance Ginner, K6GSJ, provided Bob Allison, WB1GCM of ARRL's Technical Lab and his team with technical advice to help getting the satellite operational again. Bob will also be at the Symposium and will give a brief talk on the refurbishment process.

The refurbished OSCAR-1 was on display at the ARRL exhibit area at the 2011 Dayton Hamvention. We look forward to having the OSCAR 1 prototype on display during the AMSAT Symposium as well as hear the CW transmissions (now managed by a PIC controller) in the 145 MHz band. 🌐

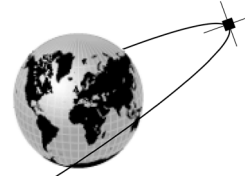
AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.





Radio Amateur Satellite Corporation (AMSAT-NA)
850 Sligo Ave., Silver Spring, MD 20910-4703
Telephone: 301-589-6062 – Toll Free: 888-322-6728
Facsimile: 301-608-3410
AMSAT-NA Club Callsign: W3ZM
AMSAT-NA Web site: <http://www.amsat.org>

The AMSAT Journal Staff

Editor-in-Chief: Ed Long, WA4SWJ, wa4swj@amsat.org
Assistant Editor: Bill Hook, W3QBC, w3qbc@amsat.org
Circulation: Martha Saragovitz, martha@amsat.org

AMSAT-NA Board of Directors

Barry Baines, WD4ASW, wd4asw@amsat.org
Alan Biddle, WA4SCA, wa4sca@amsat.org
Tom Clark, K3IO, k3io@amsat.org
Drew Glasbrenner, KO4MA, ko4ma@amsat.org
Lou McFadin, W5DID, w5did@amsat.org
Tony Monteiro, AA2TX, aa2tx@amsat.org
Gould Smith, WA4SXM, wa4sxm@amsat.org
First Alternate: **Mark Hammond**, N8MH, n8mh@amsat.org
Second Alternate: **Patrick Stoddard**, WD9EWK, wd9ewk@amsat.org

AMSAT-NA Senior Officers

President: Barry Baines, WD4ASW
Executive Vice-President: Open
Treasurer: Keith Baker, KB1SF/VA3KSF
Secretary: Alan Biddle, WA4SCA
Manager: Martha Saragovitz
Vice-President, Engineering: Tony Monteiro, AA2TX
Vice-President, Operations: Drew Glasbrenner, KO4MA
Vice-President User Services: Gould Smith, WA4SXM
Vice-President Human Spaceflight: Open
Vice President, Marketing: Open

Honorary Positions

Immediate Past President: Rick Hambly, W2GPS
President Emeritus: Tom Clark, K3IO
Founding President: Perry Klein, W3PK

Editorial Office: Ed Long, WA4SWJ, 4420 SE 106th ST, Belleview, FL, 34420-6835. Please e-mail Journal submissions to: journal@amsat.org, Editor's telephone: 262-374-1349 (cell). Advertising Office: AMSAT-NA Headquarters, 850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703, Telephone: 301-589-6062.

The AMSAT Journal (ISSN: 1407-3076) is published bi-monthly (Jan/Feb, Mar/Apr, May/Jun, Jul/Aug, Sep/Oct, Nov/Dec) by AMSAT-NA, 850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703. Telephone: 301-589-6062, fax: 301-608-3410. Periodicals postage paid at Silver Spring, MD and additional mailing offices.

Postmaster: Send address changes to *The AMSAT Journal*, 850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703.

Opinions expressed in *The AMSAT Journal* are those of the article authors and are not necessarily those of AMSAT-NA. Copyright © 2011 by AMSAT-NA, The Radio Amateur Satellite Corporation. AMSAT is a registered trademark. Reproduction of material from *The AMSAT Journal* by mechanical, electronic, photocopy or other means is prohibited unless written permission is obtained from the author.

The AMSAT Journal staff is always interested in article submissions. Whenever possible, submissions should be sent via e-mail to journal@amsat.org using plain text or word processor files; photos or figures in TIF, GIF or JPEG formats. Kindly do not embed graphics or photos in your manuscript - we prefer receiving those as separate files. AMSAT-NA reserves the right to select material for *The AMSAT Journal* based on suitability of content and space considerations. The editors of this publication are volunteers serving freely of their talents, time and efforts to produce *The AMSAT Journal*.

Success! The deployment of ARISSat-1/Kedr on 3 August 11 is a significant achievement for Amateur Radio. Through a cooperative effort between AMSAT, NASA and RSC-Energia, a unique satellite was released during a Russian EVA that has caught the imagination of Amateur Radio operators all over the world. ARISSat-1 is designed to be an engineering test bed for the placement of new technology into space as well as providing a unique platform for education outreach.

August 3rd was set to be the culmination of a long journey for the deployment of ARISSat-1. The range of recent hurdles and challenges that were met prior to deployment were significant following 4+ years of development work that involved more than 40 volunteers that resulted in the satellite being completed last October, included:

- Gaining NASA/RSC-Energia approval to allow ARISSat-1 to be shipped to the ISS (following a three phase Payload Safety Review process)
- Shipping the satellite to Russia
- Adding the battery and the Kursk Experiment by our Russian partners, including Sergey Samburov, RV3DR
- Meeting the delivery deadline of the satellite to Baikonour Cosmodrome for placement on a Progress Cargo Vessel to take the satellite to the ISS
- Shipment of the satellite to the ISS onboard Progress 41P which arrived at the ISS on January 29, 2011
- Being informed that the satellite would not deploy in February 2011 as originally planned but deferred to a later EVA in August to permit the satellite to be on board the ISS during the 50th anniversary celebration of Yuri Gagarin's flight
- Subjecting ARISSat-1/KEDR to a series of unexpected operating tests on the ISS using a battery that had been initially charged back in December 2010.

Finally, we were going to see our baby fly (after the battery was recharged in July) on August 3rd.

On the morning of the deployment, a conference bridge was set up that included Gould Smith, WA4SXM, (ARISSat-1/Kedr Project Manager), Lou McFadin, W5DID, (ARISS Hardware Manager), Tony Monteiro, AA2TX, (AMSAT VP-Engineering and

developer of the SDX software flown on ARISSat-1), Barry Baines, WD4ASW, (AMSAT President), Mark Steiner, K3MS, (ARISS-I VP and ARISS Deputy Program Manager, based at Goddard Space Flight Center), Claire Fredlund of US Orbital Sciences Corp (who guided us through the Payload Safety Review Process), Dave Taylor, W8AAS, (ARISS Training Manager and AMSAT's US delegate to ARISS-I), and Kenneth Ransom, N5VHO, (ISS Ham Radio Project Engineer, based at Johnson Space Center). Mark Severance, N5WFX, (ISS National Lab Manager, based at Johnson Space Center) was not on the call, but was in communication with Mark Steiner via cellphone and text messaging as he was in the ISS Operations Center in Houston monitoring the deployment.

The deployment was delayed because of concerns whether the 70 cm receive antenna was installed on the satellite. As the ARISSat-1 team watched the Russian EVA and saw the satellite exiting the airlock, it appeared to us that the dummy load rather than the antenna itself was installed since we could not see the 8" antenna whip. Fortunately, we were able to pass our concerns to Mark Severance who relayed our concerns to the ISS team monitoring the deployment. These concerns were passed to Ground Control in Moscow. The order was subsequently given to the Cosmonauts just as they were about to release the spacecraft to hold onto the satellite, place it in the airlock and continue with their other tasks as the cosmonauts could not confirm that the 70 cm antenna was installed. Indeed, one cosmonaut stated that he wasn't aware that a second antenna was supposed to be mounted on the space frame.

While the cosmonauts continued on their other tasks, we attempted to contact Sergey Samburov, RV3DR, to confirm the status of the 70 cm antenna. Sergey was the person who tested the satellite in Moscow and supervised the addition of the Kursk Experiment to the satellite. He insisted that the proper antenna was installed.

It now appears that rather than leave the dummy load on the 70 cm antenna port until just prior to deployment when the 70 cm was

continued on page 20 ...



Working the Japanese Amateur Radio Satellites

by Keith Baker, KB1SF / VA3KSF, kb1sf@amsat.org

(The bulk of this article was previously published as "Spotlight on the Japanese Amateur Radio Satellites" in the August 2011 issue of Monitoring Times, Brasstown, NC 28902)

In previous columns, I've been showing readers how to equip their stations, watch for, track and then (for those so licensed and equipped) actually work through our various Amateur Radio satellites now in orbit.

In this installment I'll be turning the spotlight on to a whole series of Amateur Radio satellites that were built, launched and controlled by our friends in Japan. One of these satellites still remains semi-operational to this day.

The FUJI Satellites

The very first Japanese Amateur Radio satellite, JAS-1a (which later became Fuji-Oscar 12 on orbit) was launched on August 12, 1986 on the very first test flight of Japan's new H-I launcher developed by Japan's National Space Development Agency (NASDA). It was part of a piggyback payload that rode into a nearly circular, 1497 x 1479 Km, Low Earth (LEO) orbit along with a Japanese experimental geodetic satellite called AJASAI (EGS). The FO-12 satellite consisted of a 26-sided polyhedron (about the size and shape of a medium-sized beach ball) and weighed in at about 50 Kg.

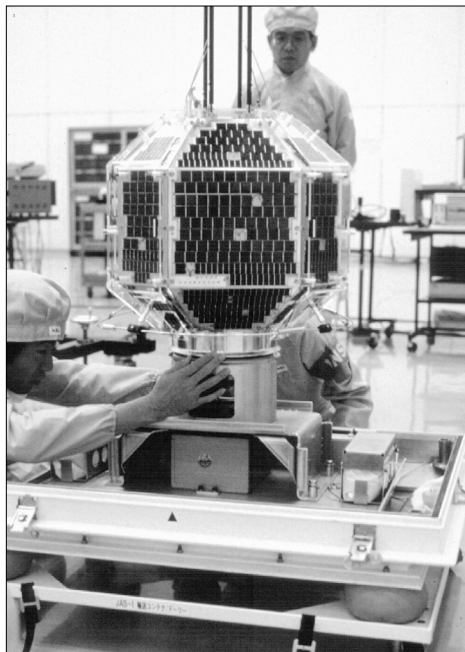


Figure 1: Technicians put the finishing touches on the launch mechanism of JAS-1b, a linear transponder-equipped satellite that later became FUJI-OSCAR 20 (FO-20) in orbit. (Courtesy JAMSAT)

FO-12 was the first Japanese amateur satellite developed by the Japan Amateur Radio League (JARL) with system design and integration performed at Japan's NEC Corporation. Unfortunately, eclipses kept FO-12 from producing enough electricity to keep it switched on for an entire orbit and it was eventually taken out of service on November 5, 1989 when the battery failed.

JAS-1b (Fuji Oscar 20)

Fortunately, Japanese hams had a replacement satellite ready for launch three months after FO-12 had to be turned off. JAS-1b became the seventh Amateur Radio satellite hurled to space in 1990 and was renamed Fuji-Oscar 20 soon thereafter. Another H-I rocket provided by NASDA ferried the 50 Kg. JAS-1b to a 750-mi.-high orbit on February 7, 1990. This H-I also carried two government satellites, MOS-1b and Debut and it marked the very first time Japan had launched more than two satellites at one time.

There were many positive features of FO-20. Its orbit was somewhat more elliptical than the most other LEO amateur satellites, so it often provided a somewhat larger footprint at Apogee and, therefore, a much larger area for potential contacts. I made many enjoyable contacts though this satellite, once I got used to FO-20's very rapid Doppler shift on the 70 cm downlink.

The Benefits of Mode J

But the 70 cm downlink was not without its benefits. Indeed, for those who were so equipped, the 70 cm downlink of FO-20 provided many users with a way to escape the inherent man-made noise that is often present on both 10 and 2 m, which, up to that point had been the "traditional" downlink frequencies for most of our Amateur Radio satellites. In many areas of the world, the 2 m band is so crowded (or filled with electrical and other noise) that it makes satellite weak signal work nearly impossible. Most of this interference is not present at 435 MHz, and

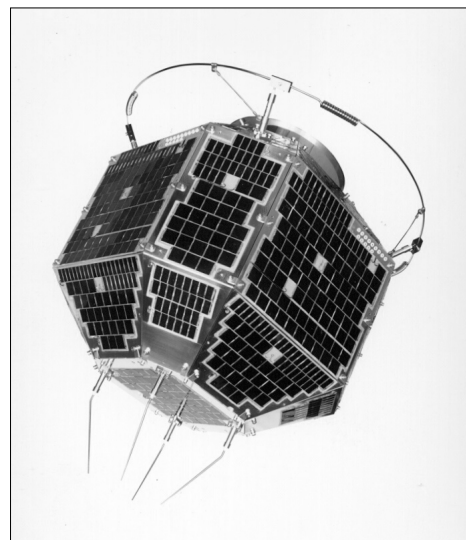


Figure 2: JAS-1b (FO-20) as it might have appeared in orbit. (Courtesy: JAMSAT)

spectrum space is somewhat less crowded at that frequency. So Mode J operation (2 m up/70 cm down) is often much preferred to Mode A (2 m up and 10 m down) or Mode B (70 cm up and 2 m down) in those areas.

Unfortunately, for all of its positive aspects, FO-20 is no longer operational. However, once again, before it went silent, our Japanese compatriots had a follow-on satellite, JAS-2 built and ready for launch.

JAS-2 (Fuji Oscar 29)

JAS-2 was successfully launched by NASDA, the Japanese National Space Development Agency, from their Tanegashima Space Center in southern Japan in August 1996 to become Amateur Radio's first new orbiting satellite of that year. As with their previous satellites, JAS-2 was principally designed by a team from the Japan Amateur Radio League (JARL) and was later built almost entirely by NEC under contract from JARL. Soon after JAS-2 successfully reached orbit, JARL requested that an OSCAR number also be assigned to their handiwork by the worldwide AMSAT community. The name Fuji OSCAR 29 (or just FO-29) was quickly

FO-29 FREQUENCY AND MODE DATA

MODE	UPLINK (MHz)	DOWNLINK (MHz)
SSB/CW - JA	145.900 - 146.000	435.900 - 435.800





Figure 3: A technician makes a final adjustment to the JAS-2 satellite prior to launch in 1996. Later re-named FUJI-OSCAR 29 (FO-29) on orbit, the satellite is still “semi-operational” to this day. (Courtesy: JAMSAT)

given to the new satellite.

FO-29 contained both an inverting linear as well as packet radio transponder on board. It also contained a magnetic torque system to spin stabilize the satellite in a planned attitude perpendicular to the orbit’s plane.

When its Mode J linear transponder was activated soon after launch, FO-29 provided very strong downlink signals, much stronger, in fact, than its aging FO-20 cousin. Also, FO-29 tended to strongly favor either left-hand or right-hand circular polarization depending on how the satellite was oriented with respect to the Earth.

Besides the stabilization system, there were many other electronic improvements carried aboard FO-29. The most obvious improvement was that, in addition to a 1200 bps AX.25 packet modem and BBS system, FO-29 also sported a 9600 baud FSK transponder as well. There was also a “digitalker” on board that stored and repeated about 25 seconds of speech unlinked from the FO-29 command station for later “broadcast” via the 435.91 MHz FM downlink. When its digitalker was activated, I still remember hearing it come over the horizon repeating the phrase “This is JAS 2” over and over again in a digitized female voice. Another, less obvious improvement included the use of gallium-arsenide solar cells with a much higher (17%) efficiency than those carried on other satellites of the era.

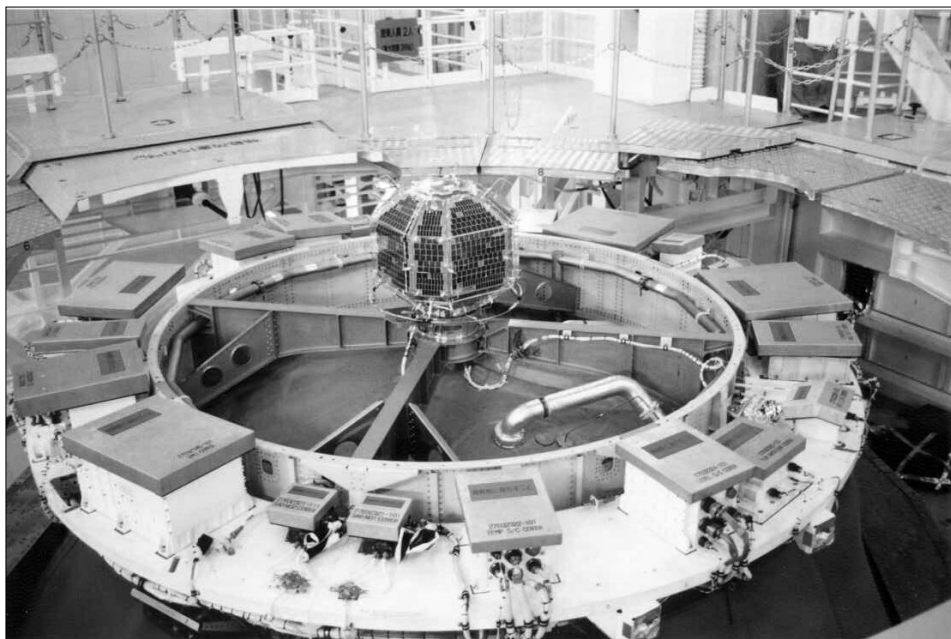


Figure 4: JAS-2 (FO-29) is dwarfed by its carrying structure. A Japanese H-II rocket launched from Japan’s Tanegashima Space Center in southern Japan successfully placed the satellite into a circular, Low Earth (LEO) orbit. (Courtesy: JAMSAT)

Unfortunately, 15 years of exposure to the harsh environment of space has now taken its toll on FO-29 to the point that only the linear, Mode JA transponder is “semi-operational”. It’s been reported that the satellite’s batteries are continuing to slowly fail due to long periods of darkness in some parts of its orbit. This condition has caused FO-29s ground handlers to keep the satellite completely switched off for upwards of several months at a time.

However, when it’s activated, this satellite is still a pure joy to work through. Hopefully,

we will get a few more years of use out of this old bird before it goes completely silent.

The latest on-orbit status of FO-29 is always available via the AMSAT Web site at: <http://www.amsat.org/amsat-new/satellites/satInfo.php?satID=5&retURL=/satellites/status.php>

Looking Ahead

In future columns, I’ll be shining the spotlight on yet another group of our Amateur Radio satellites. See you then! 📡



AMSAT Fox CubeSat Program Update

by Tony Monteiro, AA2TX, aa2tx@amsat.org

Introduction

A CubeSat is a relatively new small satellite concept that was originally proposed by Stanford University Professor and AMSAT member Bob Twiggs, KE6QMD. He and Professor Jordi Puig-Suari of Cal Poly collaborated and published the CubeSat Design Specification. Their main purpose was to try to reduce launch costs so that university students could participate in the development and operation of a real, albeit tiny, satellite.

While AMSAT has pioneered the development of small, low-cost satellites, the CubeSat concept takes this idea even further (and smaller!). Our AO-51 satellite is a relatively tiny 10-inch cube that weighs less than 25 pounds. A basic CubeSat on the other hand is an even smaller 4-inch cube and weighs less than 3 pounds. AMSAT has adopted the CubeSat idea for our next satellite project to take advantage of the low launch costs. The small size however, does pose some interesting design challenges. The AMSAT Board of Directors approved the Fox satellite project in late 2009, but with ARISSat-1 development still in full swing, it had to be deferred.

Just a few days after completion of ARISSat-1, the Fox program was started. Several of us met at the 2010 Space Symposium and got together to discuss ideas. Over the next several weeks, these ideas were further developed and finally formalized in a System Requirements Specification document in January of this year. The spec incorporated many ideas that had never been tried before on a (1-Unit) CubeSat. These included deployable solar panels, an advanced power system, a high-performance processor, a LINUX-based operating system, a software upload capability and a software-defined transponder (SDX) that could support linear and digital modes. Since the battery in AO-51 was known to be having problems, the specifications also included a hardware, analog FM transponder so the Fox satellite could be flown as an eventual replacement for AO-51.

Concept Review

The engineering team has been working on high-level designs for implementing the new satellite and got together at the end of April to have a Concept Review. Many innovative ideas were presented and there

was good progress in many areas. A number of significant problems and issues were also identified.

One key problem area was in thermal and power analysis. These are closely related because they are both driven by the illumination and infrared radiation that

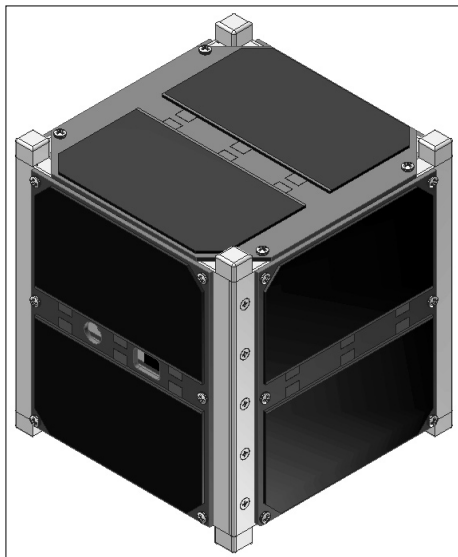


Figure 1: CAD Drawing of Fox-1 by KF4KSS

the satellite sees in orbit. Thermal analysis is critical to understand the temperature extremes that the avionics will experience and the power available from the solar panels is one of the most important elements needed in the satellite design. This is especially true for a CubeSat as the power available will be quite limited due to the small size of the solar panels.

There were significant problems with the tool chain that had been used on previous AMSAT projects. The optical and IR radiation analysis tool set, NEVADA/VEGAS, uses orbital elements as input but we did not have a good tool to produce them. The satellite will use magnetic stabilization which causes on-orbit maneuvering but again there was no good way to generate the input data needed to model this. Unfortunately, these tools are very expensive and there are no “open-source” or free versions available as an upgrade. As a result, a tedious trial and error approach as well as a certain amount of guesswork was needed to generate the input.

After the NEVADA/VEGAS tools are run, the output files are incompatible with the input format needed by the SINDA thermal

analyzer tool. This required tedious hand editing of intermediate files and results in a loss of traceability.

This situation was deemed unacceptable for the new Fox program so Dick Jansson, KD1K, and Bob Davis, KF4KSS, set to work to improve this process. They have made substantial improvements including a new GUI tool to generate orbital elements and a format converter tool to eliminate hand editing of intermediate files. As of July, they were able to complete a detailed analysis of the thermal and power available for the basic CubeSat without the deployable solar panels. While this has been tremendous progress, there is still much work needed to add the analysis of the deployable panels.

Another key issue noted at the Concept Review was the need to study the radiation sensitivity of our high-performance processor. We had selected the TI OMAP-3 processor, which was developed for use in new smart cell phones since it could provide both the internal housekeeping (IHU) functions and a software defined transponder (SDX) capability. It is a physically small, highly integrated chip set which helps fit into our limited space and was specifically designed for battery power operation.

It soon became clear that due to the radiation, error-correcting RAM would be required to make this work. This adds significant complexity to an already challenging design but Bdale Garbee, KB0G, and Keith Packard, KD7SQG, agreed to take on this challenge. However, there was also a major concern about the long-term survivability of the device itself.

Since it was designed for cell phones not satellites, the manufacturer has not published radiation test results on the device. In May, Alan Biddle, WA4SCA, joined the team to take on the challenge of flushing out the radiation issues. He has made good progress in modeling the radiation environment using the SPENVIS tools that are available from the European Space Agency (ESA.) Although we have not been able to identify any actual test data, two different experts gave us their opinions that the device would only last about 1 year in orbit. This would not be acceptable for the Fox satellite. Alan has been working our AMSAT “friends and family” network to try to find a way to conduct our own radiation test on a prototype

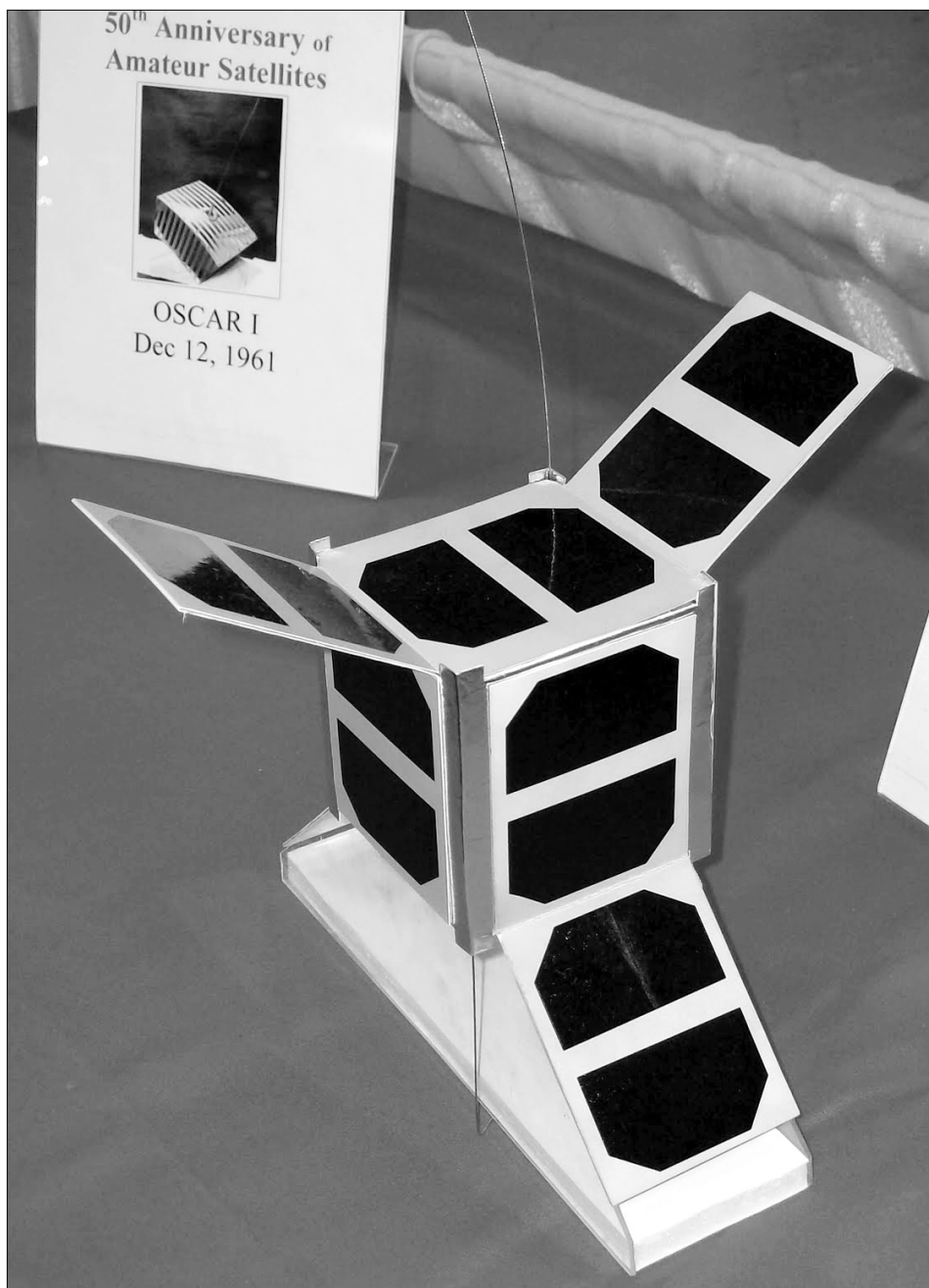


Figure 2: Fox-2 CubeSat Model by KF4KSS. (photo by KB1SF)

processor unit but so far we have not been able to do that. We need to have confidence that the device will survive before going further down this path.

New Strategy

Identifying, analyzing and solving these types of problems is a normal part of any advanced research and development project. Thorough analysis and in-depth technical work is always needed to be successful when pushing the technology envelope. It takes a certain amount of creativity, effort and time to sort out the issues.

When we started on Fox, the AMSAT operations team had noticed problems with the battery on AO-51 but the satellite was

still working quite well and we were not expecting to need a replacement in the immediate future. Since that time, one of the cells of the battery has shorted and another cell has become weak leaving AO-51 in a precarious state. The operations team has done a great job keeping AO-51 running, but it has become crystal clear that we need to develop a replacement satellite sooner rather than later.

To be more responsive, the Fox project is being split into a complementary pair of satellites named Fox-1 and Fox-2. Fox-1 will address the need to quickly develop and launch a replacement for the rapidly fading AO-51. The advanced technology work will

continue and become Fox-2.

Fox-1 Overview

The primary mission of the Fox-1 satellite is to provide a wide-area, Amateur Radio communications capability that can be accessed using very simple ground station equipment such as a handheld FM transceiver paired with a small, handheld beam antenna. This is our intended replacement for AO-51.

In our power baseline analysis, we found that we would have enough power to run a basic FM transponder without requiring deployable solar panels. Eliminating the panels significantly simplifies both the mechanical design of the structure as well as the power system electronics.

To maximize the effectiveness of the power available, Fox-1 will use 2 m for the downlink and 70 cm for the uplink. The lower path loss on 2 m will make the satellite quite a bit easier to receive than if 70 cm were used and the uplink will still be sensitive enough to allow access with only an HT driving a hand-held beam.

Providing only an FM transponder will allow the use of a high-efficiency, class-C, RF power amplifier and further optimize the use of the limited power available. We expect to be able to provide at least 400 mW EIRP on the downlink.

The satellite will use magnetic stabilization and we are working on way to deploy a full-sized, 2 m dipole antenna that will be aligned with the earth's magnetic field. This is no small feat as the antenna will be many times larger than the satellite.

Fox-1 will be designed for a sun-synchronous, circular orbit at 650 km rather than the 800 km of AO-51. This will still provide a pretty good communications range while having somewhat lower path losses. At 650 km, we will easily meet the CubeSat spec's debris mitigation requirements since the orbit will naturally decay in about 25 years. The radiation exposure will also be lower which will help prolong the life of the electronics and there are plenty of launch opportunities available to 650 km as well.

The IHU will likely be based on a low power 16-bit microcontroller with a hardware-based command decoder. The IHU will be used primarily to collect and send telemetry information and to run a science experiment. It will not be mission-critical for the FM transponder which will be designed to continue to operate in the event of a



processor failure. This significantly reduces the importance of radiation sensitivity.

We have not yet determined the specifications for the science experiment but we plan to continue our partnership with SUNY Binghamton and have it developed by senior engineering students as their capstone design project for the 2011-2012 academic year. After completion, the student experiment will be integrated with Fox-1 and will be operated in orbit by AMSAT.

We believe our ongoing partnership with SUNY Binghamton will help us to qualify for NASA's Educational Launch of NanoSat (ELaNa) program. This program provides subsidized CubeSat launch opportunities but had previously been available only to universities. It was changed this year and now non-profit organizations like AMSAT are permitted to participate. We will significantly reduce our launch costs if our proposal is accepted. Of course, there is no assurance that our proposal would be accepted but we would still be able to purchase a launch as we had originally planned. In any case, we will be targeting a launch date for Fox-1 in the second half of 2013.

Fox-2 Overview

The work on Fox-2 will continue so that we will be in a position to include more advanced technologies in our next satellite. For example, it is critical that we continue our radiation studies to understand the processing capabilities that can be made available on a CubeSat. We would still like to fly a software-designed transponder (SDX) on a long-life mission but we need to understand the survivability of the available components.

With Fox-1 providing an FM transponder, the Fox-2 design will instead focus on a linear transponder. A good linear transponder requires considerable power to run so Fox-2 will need a cutting-edge spaceframe with deployable solar panels to provide this power. The panels will drive an advanced power system with maximum power point tracking to squeeze the most out of these panels. This will require considerable research and design work.

The target orbit for Fox-2 will be a circular and sun-synchronous at 800 km like AO-51. This would provide a good communications range and CubeSat launches to this orbit have been readily available. At this altitude however, the radiation environment is harsher, which re-enforces the need to

continue the radiation studies. We would also need to find a way to meet the CubeSat debris mitigation requirements since a basic CubeSat in this orbit might not decay for 100 years.

With a more powerful processor and more power available, Fox-2 could support a much more advanced science mission. This opens up additional possibilities for collaborating with university researchers and could help us in partnering for additional launch opportunities. While there are still many unknowns and much research to be done, we are targeting a launch in the 2015 time frame.

Summary

AMSAT has adopted a new strategy for the Fox program. Rather than develop a single, multi-mission (and very complex) satellite, we will develop a much simpler FM transponder satellite, Fox-1, as a replacement for AO-51 and Fox-2 as an advanced-technology, linear transponder satellite.

This new strategy eliminates several major technical risks from the Fox-1 design. That will allow us to have a replacement for AO-51 in a much faster time frame and the engineering team will more quickly gain experience in the full development cycle of our first CubeSat. It also may allow us to qualify for the 2011 NASA ELaNa program.

Eliminating the need for an FM transponder will also help reduce the complexity of the Fox-2 design and will provide a clearer path to a new linear transponder satellite. We hope to learn from the experience of developing Fox-1 and incorporate our new knowledge into the design of Fox-2.

There are still many opportunities for designers interested in working on these satellites especially in the areas of project management, systems engineering, thermal analysis, mechanical design, electronics design, system test and test equipment development. If interested, please send email to Tony Monteiro, aa2tx@amsat.org. Thank you! ☺

Fox-1 Summary
650 km orbit
No deployable solar panels
FM transponder
Simple IHU for telemetry and command
Intended as AO-51 replacement
2013 launch target

Fox-2 Summary
800 km orbit
Deployable solar panels
Linear Transponder (SDX)
Powerful IHU running Linux
Advanced experiment support
2015 launch target

THE R.F. CONNECTION

*"Specialist in
R.F. Connectors and Coax"*
<http://www.therfc.com>

301/840-5477
Fax 301/869-3680
E mail: rfc@therfc.com

Order Line 800/783-2666
Suite 11, 213 N. Frederick Ave.
Gaithersburg, MD 20877



Crossed Moxon Turnstile for Satellite Users

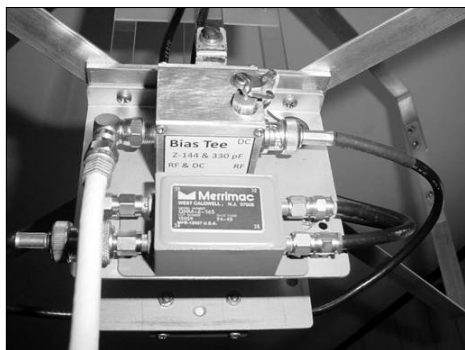
by John M. Franke, WA4WDL, jmfranke@cox.net

Introduction

There are many satellite enthusiasts that monitor, track and experiment with satellites other than Amateur Radio satellites. The other satellites include weather, navigation, environmental and even military. Technology and techniques used by one group of enthusiasts can be used by the others. I was interested in weather and navigation [1] satellites before Amateur Radio satellites. Both groups benefit from seeing what each other is doing and how they are doing it.

Common Need

One technology of common interest is the development of omnidirectional antennas, particularly antennas suitable for use in one's attic far from the prying eyes of homeowner associations. Early weather satellite enthusiasts, like early OSCAR users, built dipole turnstile antennas. Soon it was found that a ground screen was preferable to crossed reflector elements and gradually people learned the best spacing between the ground plane and the driven



Hybrid coupler and homebrew bias tee.

elements to produce a pattern that was squashed at the zenith and bulged towards the horizon thus moving the peak gain away from the zenith and closer to the horizon to compensate for the losses due to the changing range as satellites moved across the sky. The turnstile can be fed with a phasing harness to respond to right hand or left hand circular polarization or the driven elements can be trimmed to produce the 90° shift. Slowly, the turnstile is being left behind for the quadrafilial helix (QFH). The QFH is more compact, does not require a ground plane, and does not need a phasing harness or network. However, the QFH is a bit harder to fabricate and the polarization sense is not easily changed.

Enter now the crossed Moxon turnstile

(CMT) antenna having lower gain, but a broader pattern, and smaller physical size than the crossed two-element Yagi or dipole turnstile yet is easier to fabricate than a QFH. The CMT can be fed with a phasing harness to respond to either right hand or left hand circular polarization. The size and fabrication ease appealed to me when I moved and decided to put an omnidirectional antenna in my garage attic for receiving Russian low orbit navigation satellites on 149.940 - 150.030 MHz. Moving my existing antenna from my workshop up into the attic to get it up higher, reduced blockage from foliage, reduced the amount of wood the signal must penetrate, and got the antenna clear of reflections and blockage from metal shelving and cabinets in the workshop and attic. To reduce signal degradation from transmission line losses, the preamplifier joined the antenna in the attic. The preamplifier power supply stayed with the main receiver downstairs in the workshop.

I had run across the CMT design in two back issues of *QST*. [2] [3] The desired frequency coverage is close to the 2 m satellite band. But, it is not close enough. I used a Web based program [4] to calculate the needed element dimensions. The program is for single Moxon antennas, but because the crossed Moxon antennas are mutually perpendicular, there is minor interaction. To broaden the antenna bandwidth and thereby reduce the construction tolerances, I decided to use aluminum flat stock available at most hardware stores for the elements. I used the program to calculate the dimensions for element widths of 1/4", 1/2", 3/4" and 1". It turned out that 1" widths would not generate a solution. 1/2" widths were too flimsy. So I decided to use 3/4" wide 1/16" thick flat stock. Allowing for the gap at the feed point and a gap where the reflector elements join, I calculated I could get by with two 6-foot lengths of the flat stock to make one CMT. The left over scrap was slightly less than 1".

Replacing the Phasing Harness with a Hybrid Coupler

Rather than worry about finding a source for the correct impedance coax cables and trimming the cable lengths correctly for a phasing harness, I decided to use a 90° hybrid coupler to create circular polarization.

The hybrid coupler would allow me to use non-critical but identical length feed cables of 50 ohm impedance and more easily switch between LHCP and RHCP by simply swapping the position of a low power termination load and the feed cable. I had a Merrimac model QHM-6-165 90° hybrid which covers 30-300 MHz with 18 dB isolation in my junk box. Mini-Circuits sells a number of reasonably priced surface mount 90° hybrid couplers covering 150 MHz. The antenna feeds are connected to ports J2 and J3. The download is connected to J1 or J4 depending on whether you want RHCP or LHCP. The unused port is terminated with a low power 50 ohm load.

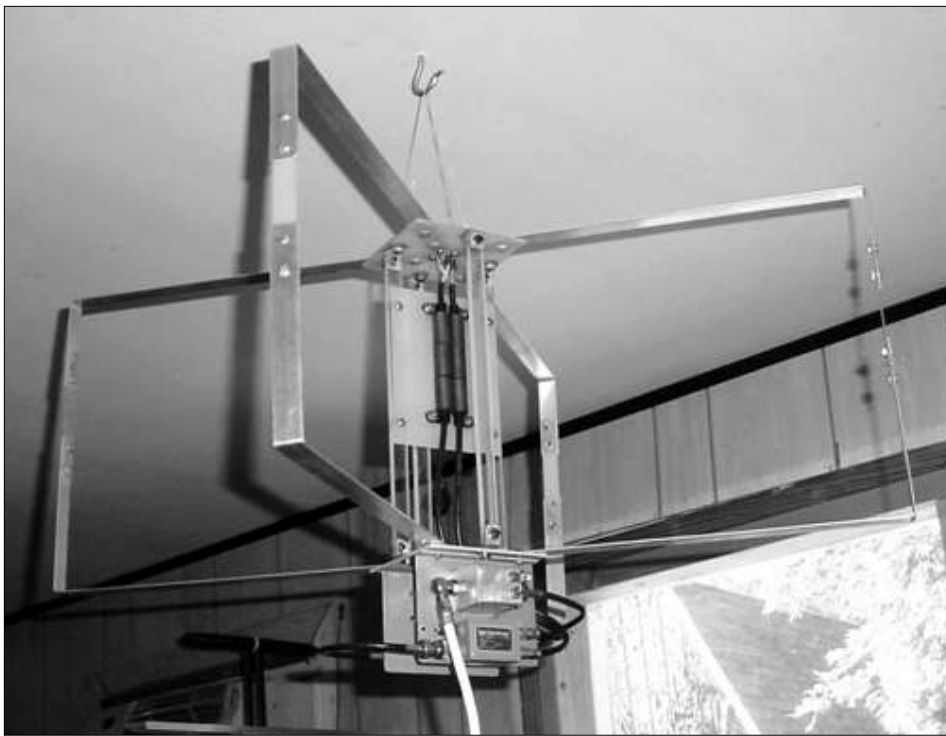


Close-up of CMT showing decoupling sleeves and top and bottom plates.

Fabrication

Fabrication started with the spacers used to hold the free ends of the elements in position. The spacers are flat strips of bare G-10 printed circuit board stock. The strips add mechanical rigidity to the entire antenna and maintain the critical end to end element spacing. Allowing for an overlap of the spacer and the element ends, I made each of the spacers 5 inches long. The spacers are 5/8" wide and 1/16" thick. I drilled four 6-32 clearance holes in each spacer. Each spacer is attached to an element pair with four 6-32 screws. Only two screws are needed, but the extra screws keep the element ends and spacer from twisting out of alignment.

Making the elements was easy, just a few



CMT hanging from workshop ceiling for testing.

measurements followed by quick cuts with a hacksaw. To avoid confusion, I marked each of the eight pieces with a Sharpie®. One mistake could have cost me a 6' length of aluminum bar stock and another day or two of delays. I sanded and trimmed the ends of the elements before bending them in a vice and then did a trial assembly. Holes were drilled in the element ends to attach the spacers, top insulator and bottom plate. The hole locations are not critical and can be seen in the Photos. I probably used an excessive number of screws, but the result is a more rigid structure and the additional screws caused no harm.

Next was the top insulator plate where the driven elements are attached. I removed the traces from a 4" square 3/32" thick piece of G-10 glass-epoxy printed circuit board. A similar size 1/8" thick aluminum plate is used to join together the reflector elements.

My first attempt for the center support post structure was four, square, aluminum posts. The posts are not resonant. They are approximately 1/8 wavelength long. The struts make electrical contact at only one end, the base. I cut four 1/2" square aluminum bars to the correct length before drilling and tapping the ends for 10-32 screws. Later, I tried another approach using 1/4" by 1/2" acrylic struts attached with small angle brackets. I found some steel angle brackets a neighbor threw out, cut them to length and filed the edges smooth. I sawed

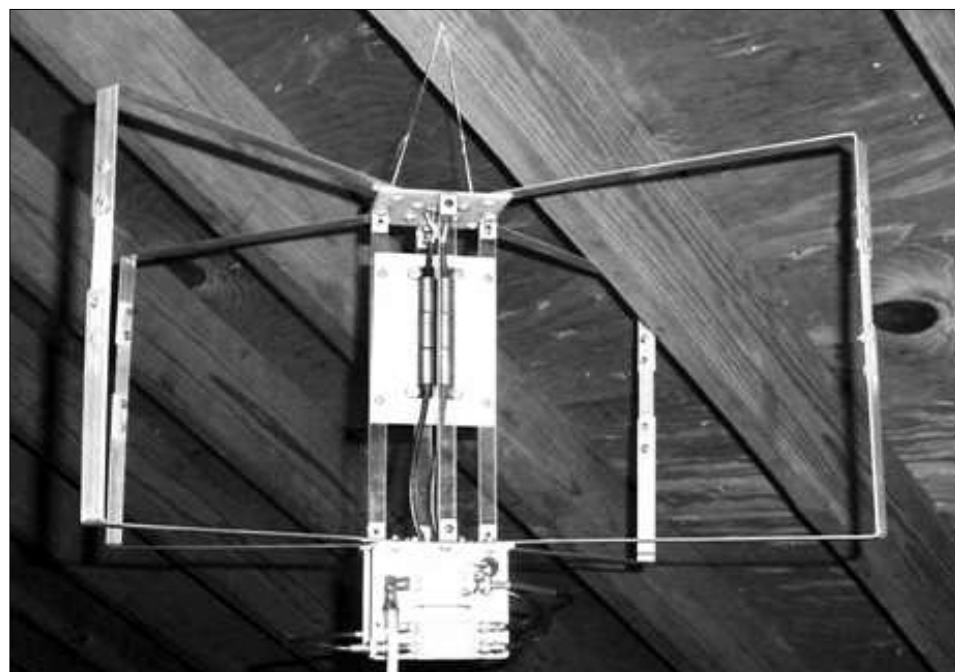
four struts from a large sheet of 1/4" thick clear plastic, sanded the edges of the struts, and drilled and tapped holes in the struts for 8-32 crews to hold the steel angle brackets. The antenna physically looks better with the insulators and probably weighs a pound or two less. The operation took a couple hours. Testing with real signals indicated changing the struts neither improved nor impaired reception. Nevertheless, the acrylic struts will remain in position unless they are

physically damaged. The photos show the acrylic struts.

I mounted an insulated plate between two of the struts to hold cable clamps for the two coax cables. The ferrite decoupling sleeves are held in position on the coax cables between two sets of cable clamps. The plate measures 3-7/8" by 5-1/4" by 1/16" and is made from a fully etched printed circuit board. I used four 1/4" nylon cable clamps to secure the RG-58 coax cables. 1/4" is a bit loose, but 3/16" was too tight. Each clamp is elevated above the plate with a pair of washers.

I used the same ferrite decoupling sleeves as used by Antony Monteiro, AA2TX, for his 144 MHz and 440 MHz Lindenblad antennas. [5] [6] I used three sleeves on each cable. The decoupling sleeves are 1-1/8" long. A SMA connector will not pass through the decoupling sleeve core, so the cables must be cut or the cables fed through before the connectors are installed.

The design feed impedance of each turnstile is 50 ohms, so the absolute cable length from each element to the hybrid coupler is unimportant, but the two coax cables do need to be the same length. I cut a single 36" long SMA male-to-male cable in half. I stripped the free ends for 1". I drilled two 3/8" diameter clearance holes in the base plate to pass the SMA coax cable connectors. Although I used crimp lugs and screws to attach the free ends of the cable to the driven elements, I soldered the wires to the lugs



CMT hanging from the attic ceiling.

without doing any crimping. Crimping did not work because I had to select larger than normal lug barrels (blue versus red). Barrels fitting the center conductor insulation were too large for crimping the small diameter center conductor wires. The cable shields are isolated from each other at the feed point. The shields are connected together only where they attach to the hybrid coupler.

I fabricated a plate from a piece of scrap aluminum with a lip to mount the Merrimac 90° hybrid coupler and attached it to the underside of the base plate using two of the screws that mount the reflector elements. Later, I mounted a bias tee to the same plate. I used silver mica 330 pF capacitors for the series coupling capacitors and Ohmite Z-144 RF chokes for the bias tees. Using bias tees eliminates having to run a separate power cable. Each bias tee has one each F connector (RF & power), BNC connector (RF only), a feedthrough capacitor (power) and a ground lug. I really like the idea of using three different connectors; it eliminates confusion and helps assure the right connections are made.

I used a Lunar 2 m preamplifier. I tested the preamplifier using a sweep generator. The preamplifier has approximately 9 dB gain and can be tuned from below the 2 m band to 160 MHz or higher. The preamplifier uses a J310 FET in a grounded gate configuration. The RF bandwidth is more than adequate. I mounted the preamplifier along with a two-terminal barrier strip on a second bracket under the CMT antenna. I am glad to have a good supply of scrap metal. The RF downlead is low loss TV/CATV cable available with connectors pre-attached from Wal-Mart, Home Depot or Radio Shack. The 75 ohm TV/CATV cable follows the preamplifier so the small impedance mismatch has little effect on the antenna performance. I used a 25' cable.

Testing

I hung the CMT from the workshop ceiling for comparison testing and added a mechanical coax switch to allow fast switching between the old and new antennas. The old antenna consists of two nested QFHs with a 400 MHz antenna positioned inside a 150 MHz antenna. The old antenna was made by CHU Associates. Both QFHs are LHCP. The old antenna stands almost 37" tall and the radome is 6" in diameter. I believe the antenna was designed for receiving signals from Navy Transit satellite navigation satellites.

I was ready for an overhead pass of COSMOS 2429 on 150.030 MHz and was not disappointed. The new antenna seemed to be quite a bit better than the old antenna. I had four minutes of solid copy and could clearly hear the satellite on the new antenna before the old antenna and eight minutes after CPA (Closest Point of Approach), long after it was no longer heard with the old antenna. Switching the termination and feed line connections to the hybrid coupler, which changed the antenna polarization, completely eliminated the signal. A pass of COSMOS 2463 (weakest of the navigation satellites) to the west of here with a maximum elevation of 32 degrees was next. I had never gotten a good telemetry decode for this satellite with the old antenna, but was able to get several minutes with the new antenna. The receiver quieting was noticeably better with the new antenna. The test results, although qualitative, definitely favored the new antenna. Telemetry was decoded with the new antenna when using the old antenna decoded nothing. At no time during any of the passages was the old antenna better than the new.

Moving the Antenna to the Attic

The attic floor is 21 inches above the workshop ceiling and includes 6 to 8 inches of insulation. My longest 5/8" diameter drill bit is 18 inches, 3 inches too short. No way was I going to be able to drill from both sides and hope to meet in the middle. The drill bit has a 1/4" shaft. I fabricated an extension from a 9 inch long piece of 1/4" steel rod and joined it to the bit using a 1/4" shaft coupler. I attached a large diameter knob on the end of a 3/8" diameter 24" long wooden dowel. The knob keeps the dowel from dropping all the way through the hole. To assist in feeding the cable up through the attic floor, I drilled a small hole through the free end of the dowel for a piece of twine to be tied to the cable. Once the hole was drilled in the ceiling, it only took a couple minutes to push the dowel down from the attic into the workshop and draw the coax cable up into the attic. I enjoy making simple tools which can be used over and over. The antenna is hung from a nail using lacing cord.

Summary

In an area with many trees, initial signal acquisition now occurs at elevation angles as low as 5°. At elevations around 15° the signal is solid copy. With the CMT down in the workshop, periods of continuous error free data exceeded 4 minutes versus 2

minutes with my QFH and with the CMT in the attic the periods are typically in excess of 8 minutes. Replacing the Lunar preamplifier with a lower noise figure, higher gain preamplifier will no doubt extend the data decoding time even more. The CMT works better than my QFH and I made it myself.

References

- [1] Franke, John M., WA4WDL: "A Time Code Reader/Display for Russian Tsikada Satellites," *Proceedings of the AMSAT-NA 14th Space Symposium, and AMSAT Annual Meeting*, November 8-10, 1996, Tucson, Arizona, pp. 150-168.
- [2] Cebik, L. B., W4RNL: Having a Field Day with the Moxon Rectangle," *QST*, June 2000, pp. 38-42.
- [3] Cebik, L. B., W4RNL: A Simple Fixed Antenna for VHF/UHF Satellite Work," *QST*, August 2001, pp. 38-41.
- [4] <http://www.moxonantennaproject.com/design.htm>
- [5] Monteiro, Anthony, AA2TX: "An EZ-Lindenblad Antenna for 2 Meters," *QST*, August 2007, pp. 37-40.
- [6] Monteiro, Anthony, AA2TX: "A Parasitic Lindenblad Antenna for 70cm" *Proceedings of the AMSAT-North America 2006 Space Symposium and AMSAT-NA Annual Meeting*, October 5-8, 2006, San Francisco, CA, pp. 53-67. 🌐

The AMSAT Store (see www.amsat.org) is back online! Here is a new AMSAT product. A handsome and functional AMSAT 10' locking carpenter's tape with both inch and metric scales.

Minimum donation: \$5



AMSAT BoD Telecon Meeting, 1 March 2011

Called to order by President Barry Baines, WD4ASW at 2002 EST.

Attending:

Directors

Barry Baines, WD4ASW

Gould Smith, WA4SXM

Drew Glasbrenner, KO4MA

Lou McFadin, W5DID

Alan Biddle, WA4SCA

Tony Monteiro, AA2TX

Others:

Martha Saragovitz, Manager

Keith Baker, KB1SF, Treasurer

Barry began the meeting with a review of HR 607, which contains a proposal to reallocate the 420-440 MHz block of frequencies away from the current primary and secondary authorizations. He has been in touch with ARRL officials who are mounting an educational and lobbying effort to contact the bill's sponsors and other senators and representatives. They are reaching out to other amateur organizations such as AMSAT to have maximum impact. Both Lou and Keith emphasized that the bill shows very little technical understanding of the issues. In addition to AMSAT's primary concern, satellite operations, it will impact terrestrial operations in Canada and Mexico and conflict with existing ITU allocations and treaties. Drew also mentioned that the Department of Defense will oppose the bill due to its interference with the Pave Paws space surveillance system.

Barry sees a need for two presidential letters. One will be to the relevant committee chairs and another to AMSAT members urging them to contact their representatives and senators. The League has offered us the use of their legislative liaison in Washington to ensure their timely delivery. Alan agreed to be the point for coordination of the effort, which will include ANS and AMSAT Web

site releases, and a downloadable letter. Keith feels that this will not be a unique circumstance, and that we need to have a lobbying plan, possibly automated, in place for future incidences.

Alan requested that the Minutes of the 2010 Chicago/Elk Grove Board of Directors meeting be approved. It was moved by Barry, seconded by Gould, and approved unanimously. The minutes will be published in the next issue of The AMSAT Journal.

The meeting then moved on to site selection for the 2011 AMSAT Symposium. Both Orlando, Florida and San Jose, California have been considered. Orlando has better accessibility and more diverse accommodations, but no one has volunteered locally to coordinate the effort. Lou said he would do so if needed. The San Jose venue already has an experienced, eager organizer. 2011 is also the 50th anniversary of Project Oscar, with largely West Coast membership. Tony added that the last West Coast meeting was very well attended. Barry moved, and Gould seconded that the 2011 AMSAT Symposium be held in San Jose, and Orlando considered for the 2012 meeting. The motion was approved unanimously.

Martha reminded the Board that we need to decide on whether to continue with a full audit, or a review. The cost difference is substantial. However a full audit is necessary for some opportunities such as the Combined Federal Campaign and potential large donors. At present the CFC donation approximately covers the difference. The Board decided to continue with the full audit.

The Board then moved on to discussions of ARRISat-1, and how to best handle the public relations considering the new deployment and operations schedule. Barry observed that this gives two opportunities. The first will be the April 12 operation to commemorate the flight of Yuri Gagarin, and then the actual deployment scheduled for a July EVA. In both cases, we need

to have information available for release. Finally, Lou, Gould and Tony covered some technical issues concerning the further development of the public ground station software, as well as the disposition of the ARISSat flight backup and spares.

Tony discussed the disposition of AMSAT equipment which has been in storage in Maryland. He and Bob Davis, KF4KSS, separated it into obsolete materials, serviceable equipment no longer needed by AMSAT which has been excessed and equipment which is being retained in small, free storage facilities. This will provide a substantial savings to AMSAT in storage costs.

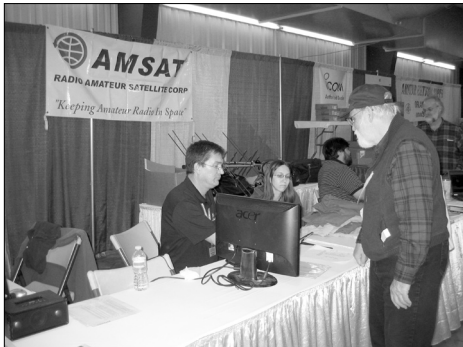
Barry and Gould reviewed numerous issues concerning AMSAT's representation at Dayton this year. This included discussions with AMSAT-China concerning their representation and Forum talk at Dayton. They are working through visa and other requirements. Martha emphasized that due to many new volunteers at the booth we need to insure their familiarity with the existing guides and update those as needed.

Barry reviewed the current efforts at obtaining a Memorandum of Understanding with the University of Florida. He is working with them to resolve several outstanding issues.

Gould finished with a brief discussion of Member Services. Efforts to update the AMSAT Web site continue, but are still a few months out. Also, discussions with G6LVB concerning the possibility of AMSAT-NA selling the FUNCube Dongle continue. At present, the final design is not formalized and many of the mass produced units require reworking. Discussions over marketing and FCC acceptance issues continue.

There being no further business, it was moved by Barry, seconded by Lou and approved unanimously that the meeting adjourn at 22:35 EST. 🌐

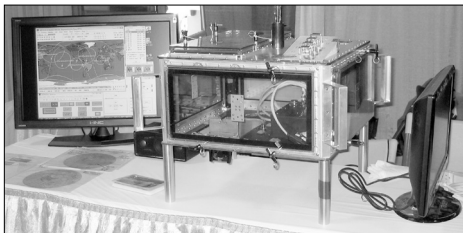
Every year in early Spring (February) the Orlando Hamcation is held at the Central Florida Fairgrounds in Orlando, Florida. This is a nice size hamfest and seems to be growing every year. While not as large as Dayton, it does attract a fairly large crowd with many vendor booths indoors and a surprisingly large flea market outdoors. AMSAT has a booth at Hamcation for several years that generates quite a lot of visitors every year. Some photos from this year's event follow.



Mike Burke, N4HHA, and his daughter at the AMSAT table at Hamcation. Mike provided the big monitor, remote amplified speaker and Internet connection that made a remote Internet connection demo with K8YSE's Internet Remote Satellite Station in Cleveland possible.



AMSAT members at Orlando included (L-R) Drew, KO4MA, Lou, W5DID, N4HHA's daughter, Mike, N4HHA, Dave, AA4KN, and John, K8YSE.



The ARRISat-1 engineering model was on display at the Orlando Hamcation booth. John summarized, "It was a very nice hamfest and we had a lot of interest at the table. My voice was hoarse after the first day. It was hard to operate because you were constantly talking with someone about satellites. There is always a lot of interest when you have something to show such as ARRISat-1 plus a full blown satellite station plus the K8YSE Internet Remote Satellite Station in Cleveland."

AMSAT is the North American distributor of SatPC32, a tracking program designed for ham satellite applications. For Windows 95, 98, NT, ME, 2000, XP, Vista, Windows 7.

Version 12.8a is compatible with Windows 7 and features enhanced support for tuning multiple radios.

Version 12.8a features:

- Select 2D/3D map with a single mouse click
- Select Political/Physical map with a single mouse click
- AOS voice announcement
- Countdown program displays next AOS of your favorite satellites
- Automatic Internet download of Keplerian elements.
- Graphical tracking on a world map with two selectable Zoom factors.
- One-click satellite switching using 12 "letter" buttons.
- Automatic rotor control support for: LVBTracker, Kansas City Tracker/Tuner, FODtrack, Uni_Trac, SatEL, Labjack U12/U3/Piggyback, W0LMD Mini/Junior/Senior Trackers, Yaesu GS-232, ARS from EA4TX, EGIS rotors, IF-100, RIF-PC, AMSAT-DL interface, WinRotor32, HalloRotor, and WiSP DDE clients.
- Doppler tuning with on-screen frequency displays. Radio models supported:
 - Yaesu FT-847, FT-736R, FT-817, FT-857, FT-897
 - ICOM IC-820H, IC-821H, IC-910H and other ICOM radios
 - Kenwood TS-790 and TS-2000
 - DDE client programs
- "Transparent" VFO-knob tuning in addition to keyboard and mouse tuning.
- "Virtual" VFO tracking for half-duplex transceivers FT-817, FT-857, FT-897, IC-706 and IC-7000.
- Includes a special version for ISS split-frequency operation.
- Controls subaudible tone on FT-847, FT-736R, FT-817/857/897, TS790A and IC-910H.
- Includes a non-graphical version and programs that output lists to the screen, printer, or a file.
- Interfaces with WiSP, with user-defined satellite switching priority.
- Includes a separate program for tracking the Sun and Moon.

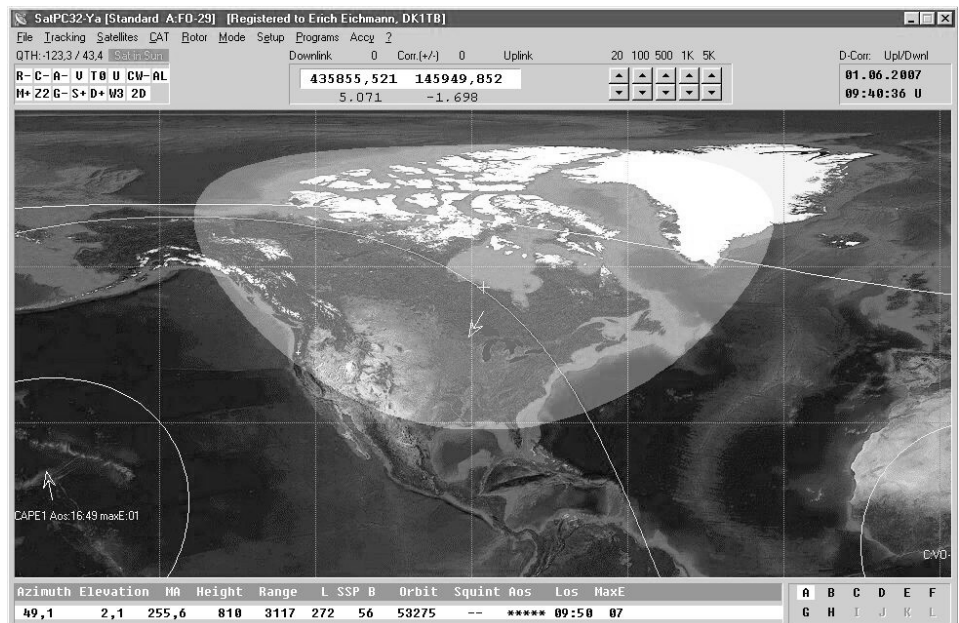
Minimum Donation is \$45 for AMSAT members, \$50 for non-members, on CD-ROM.

A demo version may be downloaded from <http://www.dk1tb.de/indexeng.htm>

A registration password for the demo version may be obtained for a minimum donation of \$40 for members and \$45 for non-members.

Order by calling 1-888-322-6728.

The author DK1TB donated SatPC32 to AMSAT. All proceeds support AMSAT.



Twins! A Backpack-Portable Full Duplex Satellite Station with Dual FT-817ND's

by David A. Palmer, KB5WIA, kb5wia@amsat.org

I've been a ham for almost two decades now and one of my favorite modes of operation is QRP (low-power) portable. There are two reasons why portable operations appeal to me: one is that it's just plain fun to operate radios in the outdoors, and the other is that I live in an antenna-restricted community so low power and low profile antennas fit in well with the neighbors. Although I had played with the orbiting ham radio satellites back in the 1990's, I had forgotten how much fun sat operation can be. Last year, after making a few contacts on the AO-51 satellite, I was hooked! I quickly realized that a portable sat station would be a perfect fit for me: low-profile and low-power operation works well for satellites, it doesn't bother the neighbors or the HOA and it's a fun addition to road and camping trips.



Operating satellite-portable in Death Valley National Park, Dave, KB5WIA, talks to Rich, N9AMW, via a low-angle VO-52 pass.

Here's how I built up my portable satellite station. It's based on twin Yaesu FT-817ND radios under computer control coupled to an Elk antenna. The system packs up small and light, travels easily and is completely full duplex. Best of all, it works very well with all of the FM and linear transponder satellites that are up there today.

Why Two Radios and Computer Control?

When operating satellites, it's very helpful to be able to hear your own downlink. This type of operation is called full duplex, and requires either a full duplex capable radio, or two separate radios (one for transmit and the other for receive). On the FM birds AO-51, SO-50, SO-67 and HO68, full duplex prevents accidentally transmitting over top of other users, and more importantly, it lets you know you're making it into the satellite (there's no need to continually

call "CQ satellite!" if you can't hear your own downlink!). On the linear birds AO-7, VO-52, FO-29 and ARISSat-1, full duplex is vitally important because it lets you hear your own downlink in the passband. This in turn lets you know where to tune to find the stations calling back to you. So either way you go it helps to have two radios for full duplex operation.

Computer control is needed to overcome the results of Doppler shift. Since the satellites are moving close to 18,000 miles per hour, Doppler shift is significant. Using a radio's fixed memory channels can often compensate for Doppler on the FM satellites, but on the linear birds, Doppler shift must be adjusted by almost continually tuning the radios. While it may be possible to manually tune two VHF/UHF radios by hand, in reality it's extremely difficult to keep up with Doppler shift within a passband by hand-tuning. Instead, using a computer to automatically tune the radio for Doppler shift makes the job much easier.

The Antenna, Feedline and Diplexer

I use an Elk Dual Band 2M/440L5 log-periodic antenna. I bought this antenna for mountain topping VHF QRP work, but quickly discovered how well it works for the amateur satellites. The antenna is dual-band and it still amazes me how a single antenna can both transmit 5W of RF and receive signals from thousands of miles away -- at the same time! The Elk is mounted to a lightweight 5-foot photo tripod with the antenna's PVC pipe mount modified to fit the quick release adapter on the tripod. In use, this arrangement allows for easy azimuth, elevation and polarization control during the pass. And the whole assembly, including tripod, folds up into a small bundle for travel.

The antenna is connected to the diplexer via a 6-foot length of RG-8X cable, terminated in PL-259 connectors from Cable X-Perts. The diplexer is a Diamond MX-72H unit that reportedly provides 60 dB of isolation between the 2 m and 70 cm input/output lines. I marked the 2 m diplexer output with orange tape, and the 70 cm output is marked with blue tape. This color scheme (orange for VHF, blue for UHF) is used to identify the appropriate cable connections throughout the whole system.

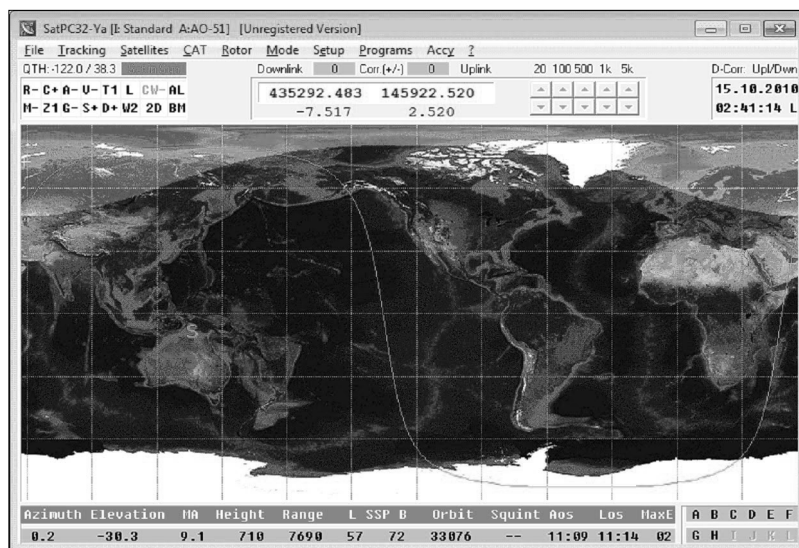
The Radios

The radios that I use are twin Yaesu FT-817ND all-band multimode portable QRP units. I originally bought an FT-817ND for camping and outdoor operation and once I started using the satellites it was an easy decision to get another one! The 817's are lightweight, portable, rugged and their 5 watt output is more than enough for all of the current satellites. Rather than having one radio dedicated to TX one to RX, I instead have one dedicated to the 2 m band (RX and TX) while the other is dedicated to the 70 cm band (RX and TX). The reason for this is that having dedicated 2 m/70 cm radios keeps me from having to swap cables on the radios. In keeping with the color scheme, the 2 m radio is marked with orange tape, while the 70 cm radio is marked with blue tape (quite necessary since both FT-817ND's look identical!). These Yaesu radios have custom display colors, so I also have the 70 cm radio set to a blue display while the 2 m radio has an orange display.

In portable use, the two radios hang via their shoulder straps from the apex of the tripod, and the appropriate cables from the diplexer plug directly into the two radios. When working satellites in V/U mode (2 m up and 70 cm down, i.e., AO-51, SO-50, HO-68, FO-29), I simply plug the microphone into the orange radio and the earphones into the blue radio. When working satellites in U/V mode (i.e., VO-52, AO-7 and possibly ARISSat-1), I simply unplug the mike and earphones and swap. The microphone is the stock Yaesu mike, and the earphones are an inexpensive pair on a retractable reel (this keeps them from getting tangled when not in use). Both radios are essentially using the default out-of-the-box settings. The two settings of importance are CAT BAUD RATE (32400) and make sure that the Squelch/RF Gain selector is set to Squelch, not RF Gain.

The PC Connection

Both radios are connected to the computer with CT-62 CAT cables. One cable is the authentic Yaesu CT-62 cable with a 6-pin mini-DIN connector on one end and a 9-pin serial DB9 connector on the other; this connects to a Cables-To-Go USB-Serial adapter. Both ends of this combined cable are marked with blue tape and are used with the UHF radio. The other cable is an all-in-one



The SatPC32 main screen.

CT-62 USB cable from Valley Electronics, which goes directly from the radio 6-pin mini-DIN to a USB connector. This cable is marked orange at both ends and controls the VHF radio. Both cables use the Prolific PL-2303 chipset and I'm using driver version 3.2.0.0 (installed in Vista SP2 compatibility mode, run as admin). The cables work equally well. Within Windows, one cable appears as COM4 (this is the orange VHF radio) and the other cable appears as COM3 (this is the blue UHF radio). I've marked the USB ports on the computer blue and orange accordingly. As long as the same cables and same USB ports are used, this numbering is consistent, so the corresponding software settings only need to be set once.

The Netbook Computer

The computer that I use is a lightweight Samsung N150-Plus netbook. It comes with Windows 7 Starter, has three USB ports and roughly a six-hour battery life. I chose the Samsung because of its matte screen. Most netbooks these days have glossy screens and I think the matte screen is easier to

view in direct sunlight. For portable outdoor operations it's important to have a screen that I can see! The backlight is plenty bright enough on the netbook to see the screen at any time of day. So far, Windows 7 on the netbook runs all the same applications as my home PC with barely any performance difference (I don't notice it any slower). To keep things simple, I set the time zone on the computer is UTC so all software runs in UTC by default as well.

The Software

The software I use for radio control is SatPC32. The software is pretty easy to use, but more importantly, works very well! I use the software with the default settings for everything except for the radio setup.

The settings I use in the radio configuration screen are dual radios, FT-817, 32400 baud and COM ports specified for each radio. The screenshot in Figure 1 shows the radio setup for the twin FT-817ND's.

To set up the linear satellites, there is an extra step when using the SatPC32 CAT control dialog box to adjust the uplink frequency

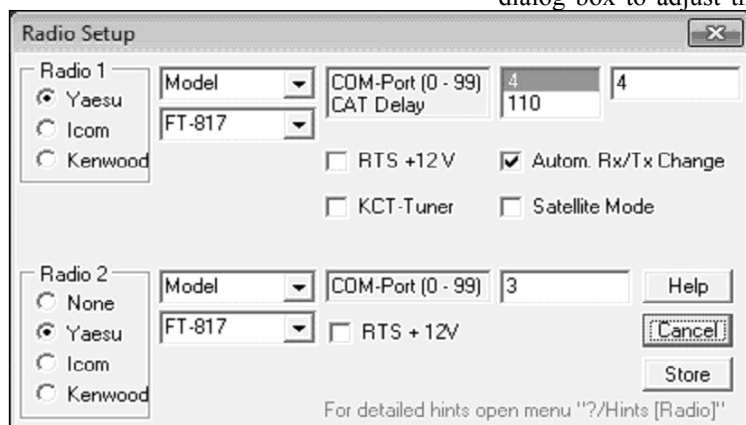


Figure 1: Dual-radio configuration in SatPC32.

adjust this a few times at first. The calibration is easily saved by pressing "Change/Store Data File"; this brings up a new box allowing you to store the new uplink calibration in the DOPPLER.SQF file. It's vitally important to keep the Keplerian Elements up to date (SatPC32 lets you download and update these with a single click) and to keep the computer clock accurate, otherwise the Doppler corrections and frequency tracking won't be accurate. I update my keps weekly and my PC clock daily.

The software I use for manually tracking the satellites across the sky is actually the satellite module from Ham Radio Deluxe (HRD). I use this software in radar mode and have the radar plot of the satellite path on the screen underneath the SatPC32 software; this way I can see exactly where to aim the antenna, since the radar plot gives a nice graphical view of direction and elevation of the selected satellite.

The radar view is also a good quick way to look for future passes. I originally tried to use HRD for both radio control and tracking, but had fits with HRD locking up under Windows 7 when controlling the radio. SatPC32 has no such problem.

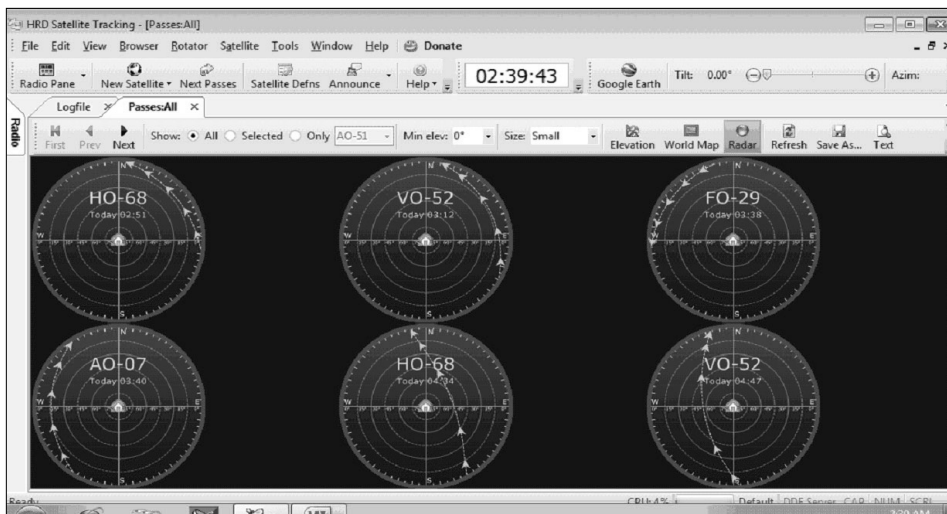
Powering it All

Everything runs on battery power, so this arrangement is super-portable! The simplest power source is to use the internal rechargeable packs on the twin FT-817ND's and the laptop and recharge them as necessary. More frequently I'll use a 7 ampere-hour sealed lead acid (SLA) battery to power both radios. The battery has an Anderson PowerPole connector with fuse on top that connects to a 1-foot long 10-gauge jumper (with ferrite cores on either end). The two radios get their power via a Y-adapter made by plugging two FT-817ND power connectors into a single PowerPole. The use of heavy-gauge wire on all but the short jumpers to the FT-817ND's prevents voltage drop that can affect the RX radio during transmit on the TX radio (important when listening to yourself on the downlink). While testing, and transmitting on 2 m with the jumper disconnected from the SLA, I managed to reset the TX radio to factory defaults (!!!) probably via RF-feedback into the 1/4-wavelength long power cord. Hence I added the ferrite cores and now I no longer transmit on internal batteries with the cord hanging loose!

Operating Notes

For portable operation, I will set up the





Ham Radio Deluxe's Radar display.

antenna and tripod, hang the radios and then plug in the power and CAT cable harness to the radios and battery. I'll then start up the netbook computer and plug the CAT control cables into the orange/blue marked USB ports. Next I start HRD to bring up the radar plot for the selected satellite and after that I start SatPC32 [1]. The whole setup operation takes about three or four minutes – it's pretty fast! Next I'll select the desired satellite on SatPC32, and turn on CAT control (C+). I like to verify the radios are tracking the frequencies shown in the software and also verify that the software frequency display tracks movement of the VFO knob on the radio used for RX. At this point, the system is ready to go – just aim antennas and talk!

Occasionally, frequency correction adjustments during the pass are necessary, but they're usually pretty minor (a few hundred hertz at most). During the pass, I aim the antenna at the portion of the sky indicated in the radar plot and I'll quickly

toggle the polarization of the antenna side-to-side to find the best downlink polarization. Depending on the satellite, polarization may change over the course of any given pass [2].

Here's the operations checklist I typically use on a pass:

- Start Netbook
- Connect orange/blue CAT cables
- Start both FT-817ND radios
- Verify mike to TX radio and earphones to RX
- Launch HRD sat tracking
- Launch SatPC32
- Select desired sat on SatPC32
- Turn on CAT control on SatPC32
- Turn on CTCSS encoding (AO-51, SO-50, HO-68)
- Verify FT-817NDs are tracking
- Turn VFO on RX radio; verify TX radio tracks freq
- Adjust uplink calibration (linear satellites only)

Results

The system works great!! The station is entirely full-duplex and I can't describe how much easier it is to work the satellites when I can hear my own downlink. Full duplex makes it much easier to aim the antenna (since I can aim it for best downlink), it makes it easier to work crowded satellites (since I can avoid doubling and conflicts), it makes working the linear satellites possible and it lets me know I'm making it into the bird to begin with. Working the FM satellites (AO-51, SO-50, HO-68 and AO-27) is easy with the computer-controlled Doppler correction and there's no more need to manually tune the VFO's. Working the linear satellites (HO-68, VO-52, FO-29, AO-07) is fun, and the system works quite well. The

only negative to the FT-817ND is that it doesn't update TX frequency while the PTT is keyed, so you need to unkey every once in a while for the TX to update for Doppler shift. It's amazing to me how well the Elk antenna and the diplexer work together [3]. It wouldn't seem possible to be able to hear a 250 mW signal coming from >2000 miles away on the exact same antenna that is transmitting 5W PEP simultaneously, but I've seen over and over again that it works - and works well!

So far, I've made quite a few contacts on all of the aforementioned birds. Operating from my antenna-restricted backyard in Northern California, from remote parts of Death Valley or even indoors during a snowstorm in Oklahoma has been no problem. When operating out in the open I have found I can easily hear myself coming back on the downlink for satellites down to about 3 degrees above the horizon (over 6,000 miles round-trip!).

Most importantly, I've found that the hams in the satellite community are a great group and I really appreciate all the help and advice they've provided so far!

Notes

- [1] If I'm operating from a different location than I usually do, I'll be sure to update my current location in both SatPC32 and HRD. Otherwise the Doppler correction will be way off.
- [2] This is fascinating in and of itself. By tracking the polarization of the satellite for best return signal you can understand how some satellites tumble in their orbit as they travel across the sky.
- [3] Thanks specially to Tim, N3TL, for describing his use of the diplexer and Elk on the AMSAT-BB mailing list. His posts (easily found by searching the Internet) enabled me to save a lot of trial and error in putting together my own system.
- [4] A recent upgrade is using a Heil Traveler headset and mic for better receive and transmit audio in windy conditions. Thanks to Patrick WD9EWK for the tip! 📶



A lightweight photo tripod holds the two FT-817ND radios and the Elk dual-band antenna.

ARISS = Education

ARISS inspires and engages youths in science, technology, engineering, math and Amateur Radio.

by Rosalie White, K1STO, k1sto@arrrl.org

US ARISS Delegate

ARRL ARISS Program Manager

ARISS-International Secretary-Treasurer

Inspire and Engage

What's the best way to tell youths about the fun and technological excitement of Amateur Radio? How about this true life scenario? Nearly 6,000 scouts learned all about ham radio in late July – at the National Scout Jamboree. Girls and boys toured the K2BSA ham stations and made QSOs over the airwaves. During the week of Jambo, license classes were held with lessons on basic electronics, radio communications and space, resulting in:

- 147 new Technician Class licensees
- 33 new General Class licensees and
- 8 new Amateur Extra Class licensees.
- Plus 210 scouts earned their Radio Merit badge!

What a score.

A large group of lucky Jambo scouts conducted an ARISS contact with Astronaut Doug Wheelock, KF5BOC, and they will never forget it throughout their entire lifetimes. Hundreds of scouts watched in awe while the ARISS contact took place, listening to Doug's answers to questions about space.

Again and Again

Every week a somewhat similar event to the above takes place. Every week an astronaut who is a licensed ham (licensed thanks to the ARISS Team, in particular, Kenneth Ransom, N5VHO, and Nick Lance, KB5KBO) supports an ARISS event. The learning activities revolving around the ARISS QSO -- lessons that are about space and wireless technology related to Amateur Radio -- could be taking place at a big camporee, at a rural or big city school, or in a science museum or planetarium where a teacher takes his or her class once a week for exciting science or technology lessons. The learning activities could also happen in any elementary, junior high, high school, or college -- maybe for engineering students -- where an educator can tie in ARISS to science, technology including wireless studies, engineering, space, or mathematics.

The goal of the US ARISS Team is this: To inspire an interest in science, technology, engineering, and mathematics (STEM)

subjects and in STEM careers among young people, using NASA missions and resources. And of course, Amateur Radio has a very strong tie to all of those STEM subjects.

ARISS is the Instigator

The ARISS-International worldwide team members represent five ARISS Regions that match up to the world's space agencies. The agencies are NASA, Canadian Space Agency, European Space Agency, JAXA, and RSA. The five ARISS Regions reflecting that are the USA, Canada, Europe, Japan, and Russia. The aim is for each ARISS Region to have 20% of the contacts. An ARISS Region may ask another ARISS Region to support a school in its place if a language barrier exists for the school/its volunteer hams and the ARISS Region team members. For instance, a Brazilian school was assisted by the ARISS Europe Team. Each ARISS Region services schools and youth groups in countries other than their own -- usually ones that are within their Amateur Radio IARU (International Amateur Radio Union) regions. For instance, Japan services schools and youth groups in Australia, and Canada services those in Central and South America.

Each ARISS Region takes very seriously the objective and challenge that ARISS equals education for youth. Within each region is a wonderful cadre of dedicated ARISS Mentors who volunteer to lead each school or youth group through the ARISS QSO, and the assignment starts months in advance. ARISS team members schedule QSOs, placing a particular school or youth group on the ARISS tentative calendar. The work ends after the QSO has taken place and the school or youth group submits a NASA evaluation and NASA surveys.

Each school or youth group that submits an education proposal usually finds a few area hams that encourage or aid the educator with lessons that have a tie to wireless technology and/or Amateur Radio to go along with lessons on space.

A myriad of other ARISS volunteers support everything that happens in between. In the USA, AMSAT and ARRL lead these responsibilities.

What Types of Education Outcomes Occur?

Wonderful examples of the education outcomes a school can garner from ARISS-related technology lessons, space lessons, and the radio contact were explained by the faculty at Midvalley Elementary School in Midvale, Utah. Midvalley Principal Carla Burningham knew about ARISS activities in other schools. So she hoped students in her school could have the benefit of ARISS because she wanted them to experience "real-life science" in their daily lives.

More than a year before the school's ARISS radio contact, while writing the required educational proposal as part of the ARISS school application, Carla and sixth-grade teacher, Dave Bettinson first researched ARRL Education & Technology Program materials (see www.arrl.org/education-technology-program). Dave knew Utah fifth grade students study a science curriculum of basic electricity. He knew Utah sixth grade students learned about the electromagnetic spectrum for part of their science curriculum. This would be the perfect tie-in to Amateur Radio and ARISS, and he could get ARRL lessons to support the curriculum.

The ARISS education activities helped him add more wireless communications and Amateur Radio in his classrooms. He had already been liberally sprinkling in NASA lessons about technology onboard the International Space Station, plus some of its history.

Every state has required science standards for students that each school must meet each year. Dave listed the following state science standards that the ARISS studies fulfilled for the sixth graders:

- 1) Manifest Scientific Attitudes and Interests
- 2) Understand Science Concepts and Principles
- 3) Demonstrate Awareness of Social and Historical Aspects of Science
- 4) Understand the Nature of Science

To ensure his educational activities about basic electricity had follow-through after the



main ARISS events were over, he used his technology lessons as a stepping off point for more in-depth science studies during the rest of the year. For details about this school's ARISS educational activities, please see ARRL's October 2010 issue of *QST*.

Carla, the principal, was thrilled to be able to exclaim a month after the main ARISS events that student interest in science, space, and Amateur Radio had greatly increased. She added that the ARISS contact itself was the best part of her 29 years as an educator because it inspired students so much! That's quite the statement!

Dave reported that student interest continued for months regarding ARISS, science, and technology, with students asking questions specific to these things. He said the ARISS contact would "reap rewards in science interest for years to come."

Schools in Your Locale

Do you know an innovative teacher who instructs classes in the sciences, technology, engineering, or math – the "STEM" classes? Or a teacher who belongs to ITEEA – the International Technology and Engineering Educators Association? Or a teacher or adult leader who works with a Challenger Learning Center or technology museum? Do you know a principal who is serious about STEM objectives? Do you know a school that specializes in the sciences? These are the perfect educators and institutions to talk to about ARISS.

Refer your educator to NASA for help with how and when to submit an educational proposal. The educator should send an e-mail to JSC-TFS-ARISS@mail.nasa.gov or call 281-244-2320. Additional information can be found at <http://www.nasa.gov/audience/foreducators/teachingfromspace/students/ariss.html>.

When you talk to educators, you can cite some of the plans and some of the terrific outcomes experienced by the Midvalley Elementary School. You can show them the October 2010 *QST* article. You can pull facts from the following reports from schools and youth groups that had robust ARISS educational activities revolving around ARISS radio contacts, the past few months:

Walnut Creek Elementary, Azle TX

This K-4 school has a new ham radio club. Students got to operate the radios and figure out the many things that can be done with ham radio. The first event was Kid's Day

with QSOs being made on HF. Students participated in hands-on mapping skills to keep track of the locations of the hams they contacted. Fourth graders (120 students) studied the Solar System, and made models of their favorite space object, researching facts about it, and writing a report they presented to other classes in the school as a part of their Space Day events. Retired Lockheed employees and members of the Tri-County Amateur Radio Club gave demonstrations on satellite communications, Sputnik model making, determination of the heat of an object traveling in space, and space station tracking. Keith Pugh continues to assist the teacher with ideas on teaching about satellites.

Jessup Elementary, Houston TX

With the help of members of the Clear Lake Amateur Radio Club, ARISS activities were integrated into the full school curriculum involving many grades. The focus was on science, technology related to ham radio, math, and language arts instruction across kindergarten through fourth grade. A variety of instructional strategies included contests for essay about space for fourth grade students, demonstrations of ham radio, discussions on the ARISS radio set-up and system, ham radio propagation, and for the youngest students, kindergartners researched space exploration and drew posters depicting it. The teachers of the gifted and talented classes planned the science lessons.

Riley Avenue School, Calverton NY

The Peconic Amateur Radio Club supported this ARISS contact. The school has many academic ties to the Brookhaven National Lab, and many parents work there. So they were very supportive of the sciences and were pleased that the ARISS educational activities could supplement the science curriculum (particularly in the third and fourth grades). Additionally, in order to involve the whole school, teachers tied in cross-curricular activities as part of the education plan, including a reading program of non-fiction books about space and the introduction of math problems related to space.

Camp Cavett, Oklahoma City, OK

Camp Cavett is for youth with terrible illnesses. Classes were scheduled two periods each day with ARRL-provided lesson plans to explain some wireless technology and radio principles including line-of-sight versus skip, what blocks signals, reflection

and refraction. The kids took part in hands-on demonstrations of HF contacts, PSK operations, and with the assistance of the FAA Aeronautical Amateur Radio Club, used their repeater for UHF operations. They had discussion for 30-60 minutes, and then afterwards, hands-on operation of the radio systems. The discussion studies included why we go to space, what makes it possible to have a space station, and how it applies to every day for youths. Students expressing interest in becoming hams were given information on how to find license classes.

National Scout Jamboree, Fort AP Hill, VA

Every 4 years, Jamboree sports 43,000 Scouts and leaders in 825 troops, plus 5,000 support staff. The K2BSA Amateur Radio Demonstration Area is a hot spot of activity throughout the Jamboree with hundreds of scouts learning about the principles of radio communications and a little about space. At past Jamborees, more than 200 scouts earned their Radio Merit Badges, and more than 100 new Technician licenses were earned. And thousands of Scouts toured K2BSA.

Space Jamboree, Rantoul, IL

The Rantoul National Aviation Center is the former Chanute Air Force Base, home of the Chanute Air Museum that exhibits aviation and aerospace items, and has technical training programs. The museum hosted "Space Jam 4" for boy and girl scouts from 4 Midwest states. Merit Badges were earned in Space Exploration, Radio, Aviation, and Electronics. Many scouts made their first QSO and learned about space, principles of ham radio communications and propagation, ham satellites, and related topics.

DaVinci Science Center, Allentown, PA

The center engaged students with its 200 hands-on exhibits and laboratory programs on science, technology, engineering, and math activities. NASA provided assistance with lessons on space. The Delaware Lehigh Amateur Radio Club provided lessons on Amateur Radio satellites, UHF modes, and SSTV.

Information can be found at <http://www.arrl.org/amateur-radio-on-the-international-space-station>

You've Located an Interested Educator

Okay, now you've found an educator whose interest is piqued. You can quickly steer your



Memories of Early Satellite Work

by David Kruh, WB2HTO, WB2HTO@comcast.net

teacher to NASA for teacher resources that can be implemented, most on space, and some on ham radio. Send the educator to: <http://www.nasa.gov/audience/foreducators/teachingfromspace/students/ariss.html> for educational resources on space.

Next lead your teacher to ARRL's range of technology lesson resources. See: <http://www.arrrl.org/classroom-activities> and <http://www.arrrl.org/amateur-radio-in-the-classroom> for ideas on activities and to read more about what other schools have done.

ARISS was and will be highly publicized by NASA, and competition regarding the education proposal will get a little tougher. A window of opportunity for submitting proposals will be opened twice a year for a particular amount of QSOs for a particular six-month period tied to each ISS Expedition. The first timeframe to have ARISS QSOs operate in this way will be January to June 2012.

For more information on the new proposal process, you'll soon see an article in an upcoming *The AMSAT Journal* or in the AMSAT Symposium papers.

The Final Word

It would have been impossible for all of this great student learning that you've read about to have taken place if we did not have the terrific ARISS volunteers worldwide. And you know who you are!

The educational outcomes would have not been seen if it weren't for NASA, AMSAT, and ARRL.

Without all of these important pieces ARISS could not exist. So the final word in this paper is: THANK YOU to all of you who work so hard on the ARISS Program. You make a difference, and you are wonderful!



In 1974 Oscar 7 (Orbiting Satellite Carrying Amateur Radio) was launched, followed four years later by the launch of Oscar 8. As a youngster who grew up thrilled by the exploits of Shepard, Grissom, and Glenn, it was exciting to think that in some small way I could experience the space program first-hand. Using an azimuthal projection and a plastic overlay of Oscar 7 orbits (I think they were included in an issue of *QST*) it was easy to determine when the satellite would pass within range. I set my Tempo One to the downlink on 10 m and could hear a number of CQs and QSOs coming from space. That was pretty cool.

But I knew that the real fun would be actually transmitting through the satellite, and so in the spring of 1977 I bought a used 2 m CW transmitter (I think it was a Hallicrafters) and built a 2 m ground plane out of coat hangers, which I hung outside the shack window. Nothing fancy, as I had recently purchased a used TH3 beam for mounting on my parent's roof (these were GREAT parents - see the photo) and knew eventually I would stack some sort of antenna for 144 - 148 MHz up there. Once I had the 2 m transmitter working, I checked my *QST* for the satellite's latest schedule and, with my high-tech plastic overlay, saw that Oscar 7 would pass right over New York on the afternoon of June 6th, 1977.

As expected, I started hearing CW signals from other stations a few minutes after 1:00 pm (EDT) on 10 m and I began sending CQ on 2 m. Nothing. Huh. Well, since I didn't have a directional antenna I kind of figured the satellite, which was orbiting about 1400 miles above, would have to be a lot closer to pick me up. So I called CQ again on 2 m CW and - BINGO! - there it was, coming back to me on 10, was my own signal. Now here's the really cool part. As I'm transmitting and the satellite is racing towards me at 17,000 miles an hour, I could hear the tone of the signal getting higher in pitch - the Doppler shift of my signal coming back from space. It got stronger too, as Oscar 7 passed almost directly overhead of me. Almost immediately the tones began to shift lower as the bird raced away and the opposite Doppler shift took effect. Well, I just thought that was the coolest thing to be able to actually hear that happening. As of this writing the experience is almost 35 years old and it is as vivid as any ham memory I have.

Two weeks later the TH3 beam was installed and shortly thereafter a Cushcraft circularly polarized antenna stacked on top, and on July 24, 1977, on Oscar 7's 12294th orbit I made my first space-based QSO, with WA4JID in Florida. I subsequently made dozens of QSOs through Oscar 7 and then, in the summer of 1978, dozens more through Oscar 8. Yet I don't recall any of those QSOs as vividly as I do when I first heard the dits and dahs of my Doppler-shifted signal coming back at me from space. 🌐





to be installed as originally planned, the 70 cm antenna was installed sometime earlier. The prior ISS crew may have installed it back in January following arrival of the satellite to the ISS when the initial communication tests using the two meter port attached to an external ISS antenna were conducted. Or, the antenna may have been mounted on the satellite prior to placement in the Progress cargo vessel for delivery to the ISS. In either case, the 70 cm antenna would have been folded over and held in position by the packaging surrounding the satellite to protect it while inside the ISS and placed in storage for almost seven months. It is possible that the sharp bending of this very short antenna and holding it in a fixed position for so long subsequently damaged the antenna. While quite flexible and designed to handle the 'bumps' of cosmonauts striking it as well as not causing damage to the cosmonaut's spacesuit, the antenna wasn't designed to be mounted on the spacecraft while in storage on the ISS since forced bending would place a strain on the whip antenna mounting point inside the base of the antenna.

The decision to deploy was made at the end of the EVA with the realization that the 70 cm antenna was not right. That decision was made because there weren't other viable options. If the satellite wasn't deployed, there were no guarantees that a replacement antenna could be flown to the ISS and the next EVA wasn't scheduled until February 2012. That is beyond the life expectancy of the Orlan silver-zinc spacesuit battery installed in the satellite as that battery has a one-year shelf life once it is activated. The likely result was that if we didn't deploy as is, the satellite would likely have been placed in a Progress cargo vessel and subsequently be destroyed upon re-entry. It was better to deploy a wounded bird than not to fly at all.

The loss of the 70 cm receive antenna would only impact the use of the 16 kHz wide transponder. While this was expected to have a major impact on Amateur Radio operations, it did not impact the educational content transmitted on the 2 m downlink. Subsequent to deployment, reports came from various sources (including AMSAT's VP-Operations Drew Glassbrenner, KO4MA) that amateurs were indeed able to hear themselves on the downlink using relatively low power on the uplink. This good news was welcomed with relief! Despite missing the whip portion of the antenna, the satellite transponder

was apparently viable. Note that if the dummy load had indeed been placed on the spacecraft, no signals would have been received thus confirming that the 70 cm antenna was indeed installed. As the cosmonauts were not aware of the existence of the second (receive) antenna, the only way that the antenna could have been mounted on the spacecraft was if it was placed there prior to the deployment and the arrival of the current crew on the ISS.

The conference bridge that was originally set up on the day of deployment was meant to be a means to help celebrate the ARSSat-1 deployment became a critical communications link between AMSAT and NASA in dealing with the uncertainties of the 70 cm antenna. I cannot stress enough the significant role that both Mark Steiner and Mark Severance played in helping to ascertain the physical condition of the spacecraft and to relay AMSAT's desire to deploy the satellite once we realized that the 70 cm antenna was indeed installed, but damaged. This support reflects the importance that NASA Education sees in the potential for the ARISSat design as a unique platform for Education Outreach.

While we are all Amateur Radio operators and have looked upon the potential benefits of having a new linear transponder in orbit, this was not the primary purpose of the satellite. ARISSat-1 deployed because of the educational content of the satellite. Both RSC-Energia and NASA are interested in seeing student experiments fly in space as well as supporting STEM education. The ARISSat design can currently accommodate up to three experiments; ARISSat-1 features one student experiment from Kursk State Technical University. The BPSK telemetry channel (using a new protocol developed by Phil Karn, KA9Q, to minimize the impacts of fading) is designed to provide not only satellite telemetry but also data from whatever payload experiments are on board. Clearly, we have successfully demonstrated the ability of the satellite to support student experiments as well as provide the ground infrastructure to receive data to support experiments.

The educational content of the satellite in terms of student involvement in generating voice greetings in 15 languages plus the SSTV imagery available from the four cameras onboard has been previously documented. What may not be so well known is that AMSAT is expected to provide

not only the satellite design and construction in support of education, but development of ground support for education as well. From a space agency perspective, ARISSat-1 must successfully compete against other education outreach opportunities given limited space agency funding if we are to see future ARISSat missions. As we've built four spaceframes in addition to the one that is currently in orbit, AMSAT is certainly looking for future opportunities.

Consequently, thanks to the efforts of Gould Smith, WA4SXM, Joe Armbruster, and others, AMSAT developed the www.arissat1.org Web site as a mechanism for reaching out to teachers and students concerning the potential for using ARISSat-1 in the classroom. AMSAT has spent considerable time developing a number of programs to encourage student participation in several ways:

- Certificates recognizing those that submit reception reports, affirming their direct reception of the satellite.
- "Secret Word Contest": Students are encouraged to listen for the secret word embedded in each student greeting that is heard on the FM downlink.
- "Chicken Little Contest": Students and others are encouraged to provide an estimate of when they expect the satellite to re-enter the atmosphere. Current altitude height of the satellite is available on www.arissat1.org through the telemetry link available on that Web site. Students are encouraged to review the progress of orbital decay to estimate when the satellite will reach the point where re-entry will occur. Recognition will be given to various age groups for coming the closest to the actual re-entry date.
- CW Contest: Identify at least six of the 200+ Amateur Radio call signs transmitted by the CW beacon. The call signs are those of individuals who have made a difference in developing Amateur Radio in space. The contest is designed to encourage students and newcomers to Amateur Radio to develop their CW skills. Electronic devices for decoding CW are not to be used in this contest.
- Telemetry Analysis: Detailed telemetry data of a satellite is being forwarded to a central site from receive stations around the world and made available



on the Internet. This data is available to all interested parties via the www.arissatlm.org site for review and analysis. For the first time, near real time (one minute updates) telemetry data is available worldwide for mobile devices. AMSAT provides telemetry software developed by Douglas Quagliana, KA2UPW/5, (PC software) and Gilbert Mackall, N3RZN, (Mac software) that can be used to collect data from the satellite via the BPSK downlink as well as for analysis of telemetry data available from the AMSAT FTP site. This new medium means that students can evaluate ARISSat-1 performance long after the satellite de-orbits and provide a mechanism for postmortem evaluation of orbital performance.

While these mechanisms are designed to enhance the educational value of ARISSat-1, it is also clear that the space agencies expect AMSAT to provide educational value by providing guidance to educators on how to take advantage of the satellite's educational content. AMSAT is traditionally an engineering-focused organization, and until the deployment, was primarily focused on the technical details of the satellite. We're challenged to develop educational materials such as lesson plans, developing various teaching ideas for use in the classroom and encouraging educators to take the time and effort to use this resource in their classrooms. Material developed for the ARISSat-1 mission is adaptable for future missions as well, so we are developing a foundation suitable for future ARISSat missions should they occur. If you're in position to assist AMSAT with developing appropriate teacher materials, please contact me as we can use additional assistance in developing these materials.

As part of NASA's evaluation of the success of ARISSat-1 in terms of educational outreach, AMSAT is in the process of submitting to NASA statistics on satellite usage. We initially reported on the number of stations submitting telemetry data to the central site. We will be reporting in September other statistics, such as the number of individuals submitting requests for certificates; the number of SSTV images filed on the SSTV server site, and updated numbers on telemetry submissions. The Chicken Little Contest will also be counted in this analysis. Douglas Quagliana, KA2UPW/5, informed the ARISSat-1 team that as of September

14, 2011, a total of 252 stations around the world forwarded telemetry to the server site providing 101,684 frames (including duplicate frames) of data! This continuing interest in telemetry collection six weeks after deployment is a very positive reflection on the interest level of the satellite.

The failure of the silver-zinc battery (a design that was never meant to be subjected to repeated charge/discharge cycles) took place earlier than expected. We are fortunate that the failure did not create a battery short thus overloading the power system and preventing the operation of the satellite in sunlight. The loss of the battery means loss of the Kursk Experiment since that experiment was designed to provide once daily data collection that would be retransmitted until a new data set was collected. With the satellite resetting in eclipse, we are unable to collect data for a full orbit and then retain that data for transmission to the ground. There also appears to be indications that the satellite may be resetting in sunlight, raising questions about what might be causing this other than lack of power in eclipse.

Despite these setbacks, the satellite continues to perform while in orbit, serving as a proving ground for new technology such as the SDX and the downlink telemetry format using KA9Q's new protocol. The off-the-shelf cameras have provided SSTV images that attract continuing interest. Clearly, ARISSat-1 has demonstrated the viability of the ARISSat design and its ability to support student payloads. Congratulations to the ARISSat-1 Engineering Team for a job well done!

Project Fox

While the excitement of seeing ARISSat-1 operate continues to capture the imagination of users on the ground, AMSAT is now focusing on our next announced project, Fox.

Back in 2009 when the Fox project was announced the focus was on creating a CubeSat that would be a true Amateur Radio satellite with both uplink and downlink capabilities. We envisioned using a UHF uplink and VHF downlink, having deployable solar panels to provide additional power, and perhaps incorporating the SDX design into the satellite allowing various operating modes or simultaneous downlinks.

Over the past two years our engineering focus was primarily on completing ARISSat-1, but starting in late 2010, AMSAT's

VP-Engineering Tony Monteiro turned his attention to building an engineering team for Fox and taking the time to do a detailed requirements analysis of a CubeSat design that met AMSAT's expectations. Tony's team has spent considerable time evaluating how AMSAT can build a satellite that meets our expectations regarding features/capabilities while recognizing both cost and time constraints. The deterioration of AO-51's batteries has increased the focus on the need to get a replacement satellite in orbit.

After doing a thorough requirements review in April, the Fox engineers have determined that the most effective approach for AMSAT to follow is to split the program into two different satellite projects. Fox-1 will be a 'simple' satellite with an FM 70 cm downlink/2 m uplink, simple control mechanisms, non-deployable solar panels, and focused on getting a replacement satellite into orbit. Fox-2 will be a more robust satellite with SDX installed, deployable solar panels for more power, higher RF output, sophisticated IHU and other technologies embedded into the satellite. This splitting of capabilities also recognizes that the more complex technology development will require more time and that we shouldn't defer getting a replacement for AO-51 in orbit due to technological issues. Along with satellite development will be efforts to secure a CubeSat launch through NASA's new program to support CubeSat deployments by schools and not-for-profit organizations.

This conclusion reflects a revised set of priorities for AMSAT versus prior projects. In the past, our tendency has been to increase the bells and whistles of satellites under development as new features and capabilities are added over time; this is sometimes called mission creep. In the case of Project Fox, our engineering team, following a review of capabilities, requirements and resource constraints is determined to resist mission creep by splitting the project into a more practical two-phase development program where the first satellite will not be impacted by development efforts of the second phase.

At the upcoming AMSAT Symposium in San Jose, CA the Fox Engineering Team will be presenting an update on their development work.

continued next page ...





LVB Tracker Box

- Reasonably priced and all profits go to AMSAT
- USB or serial interface
- Ethernet interface capable
- Open software
- Open architecture
- Built-in rotor interface cable with DIN connector
- Power supplied via the rotor controller cable
- Bi-directional interface allows the unit to read the rotor position
- LCD position readout
- Front panel manual control
- Self-programmable, allows for easy software upgrades
- Supported by the major tracking programs
- Uses GS-232A or Easycomm I/II protocols

Contact Martha at the AMSAT office 301-589-6062 to order.

The complete units will be built in groups, so get your orders in early. Units will be shipped as they become available.

Minimum donations requested for various configurations:

- 1) Bare board - \$20 + S&H - no parts kits available
- 2) Populated board, serial interface - \$100 + S&H - no kit with USB unit, rotor cable and LCD available, we do have a parts list with recommended part numbers and sources.
- 3) Custom Ten-Tec Enclosure powder coat, silk-screened, drilled/punched - \$50 + S&H
- 4) Complete unit - board, USB output, rotor cable, LCD, enclosure - \$200 + S&H **our most popular

Documentation for the LVB Tracker can be found at: <http://www.LVBTracker.com>

Boards and complete units may be ordered from the AMSAT office at 301-589-6062 or from martha@amsat.org



Apogee View

new Symposium chairman, Alan Bowker, WA6DNR, is busy making preparations. Along with the many facets of Symposium that have become the norm, such as quality presentations, lots of opportunities to socialize with other attendees and our banquet, we are also taking time to celebrate the 50th anniversary of OSCAR-1, launched in December 1961. The ARRL has graciously agreed to bring their OSCAR-1 prototype (one of three devices built, one is in the Smithsonian and the other was the flight unit) to Symposium. Refurbished in 2011, the prototype transmits a low power CW signal. We are also pleased that Lance Ginner, K6GSJ, will be our Saturday evening banquet speaker. Lance was involved with the development of OSCAR-1 and enjoyed a distinguished engineering career. For more information about Lance, see the article published in the September/October 2006 issue of *The AMSAT Journal* as well

as the AMSAT Web site pages pertaining to Symposium.

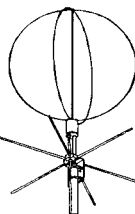
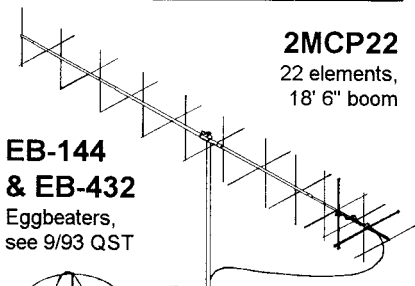
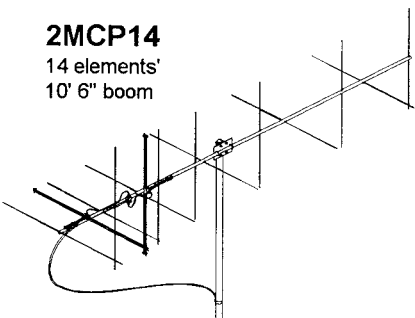
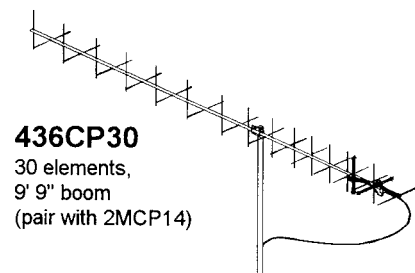
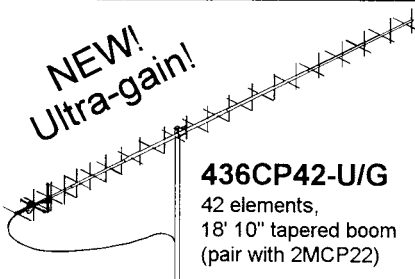
Details on the Symposium, including registration and hotel information may be found on the AMSAT Web site. We look forward to seeing you in San Jose!

73,

Barry A. Baines, WD4ASW
AMSAT President

M² YOUR SATELLITE ANTENNA SOURCE

NEW!
Ultra-gain!



- Stacking frames
- AZ & EL positioners
- Fiberglass crossbooms
- Power Dividers
- Phasing harnesses

M² 4402 N. Selland
Fresno, CA 93722
(559) 432-8873 FAX: 432-3059



AMSAT[®] President's Club! Join Now!

Contribute to **AMSAT[®]** directly through easy, automatic charges to your credit card.
Donations may be USA tax deductible. (Check with your tax advisor.)

Titanium Donors contribute at least US \$400 per month.

Every **Titanium Donor** receives gifts of:

☐ \$400 / month

- ✓ Everything at the Platinum Donor Level, PLUS:
- ✓ A very special, *hand crafted*, AMSAT President's Club Donor's pin.

☐ \$4800 one time

Platinum Donors contribute at least US \$200 per month.

Every **Platinum Donor** receives gifts of:

☐ \$200 / month

- ✓ Everything at the Gold Donor Level, PLUS:
- ✓ A very special, *hand crafted*, AMSAT President's Club Donor's pin.

☐ \$2400 one time

Gold Donors contribute at least US \$100 per month.

Every **Gold Donor** receives gifts of:

☐ \$100 / month

- ✓ Everything at the Silver Donor Level, PLUS:
- ✓ A personal invitation to the AMSAT Dayton dinner (free).

☐ \$1200 one time

Silver Donors contribute at least US \$50 per month.

Every **Silver Donor** receives gifts of:

☐ \$50 / month

- ✓ Everything at the Bronze Donor Level, PLUS:
- ✓ A personal invitation to a reception with the AMSAT Directors, Officers and project designers and builders (free).
- ✓ Annual endorsement sticker after each year of donation.

☐ \$600 one time

Bronze Donors contribute at least US \$25 per month.

Every **Bronze Donor** receives gifts of:

☐ \$25 / month

- ✓ A unique "AMSAT President's Club" certificate.
- ✓ A specially designed AMSAT President's Club Donor pin.

☐ \$300 one time

Core Donors contribute at least US \$10 per month.

Every **Core Donor** receives gifts of:

☐ \$10 / month

- ✓ A specially designed AMSAT President's Club Donor pin.

☐ \$120 one time

Choose where your contribution should go:

☐ AO-Echo ☐ AO-Eagle ☐ ARISS ☐ Future Projects ☐ General Fund

☐ RENEW my
President's Club
AUTOMATICALLY
every year!

☐ I prefer to make my donation in one yearly payment of \$ _____.

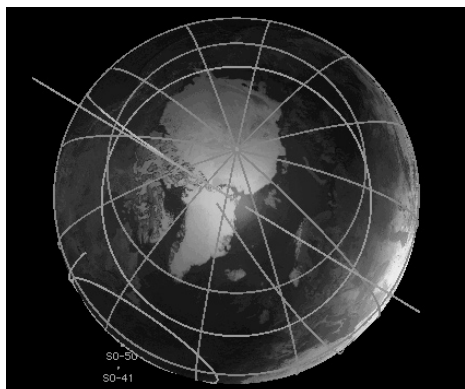
(Credit card only, please.)

THANK YOU!



MacDoppler

The premier Satellite tracking and station automation application for the Macintosh - OS 9 & OS X



MacDoppler for Cocoa gives you a seat right in the heart of the Operations & Command Centre for every satellite in orbit, providing any level of station automation you need from assisted Doppler Tuning and Antenna Pointing right on up to a fully automated Satellite Gateway !

It will calculate the position and relative velocity of the satellites you are tracking and automatically adjust the Doppler shift on both transmit and receive as well as pointing your antennas with predictive dead spot crossing so that a pass is never interrupted.

A Universal Binary that runs native on Intel and PPC Macs and provides separate panels for the map (2D or 3D), the radio and rotor controls, a sorted table of upcoming satellite passes and a Horizon panel that graphs upcoming passes as a function of elevation over time.

Now available from AMSAT at a special member discount donation!

martha@amsat.org
850 Sligo Ave.,
Silver Spring MD,
20910-4703 USA.
(301) 589-6062, (301) 608-3410 (Fax)

Dog Park Software Ltd.
www.dogparksoftware.com

Do you still use manual tuning to remove Doppler changes? Why not automate? **Uni-Trac 2000** will automatically tune your Receiver (and Transmitter) to compensate Doppler frequency changes. Uni-Trac will also **STEER** your Antenna !

Uni-Trac 2000, including Interface Cable \$280.00
FOB Concord, Mass. 01742, USA.



Spectrum International, Inc.,
P.O. Box 1084,
Concord, Mass. 01742, USA.
Tel: (978) 263-2145
Fax: (978) 263-7008

Help Wanted AMSAT needs qualified volunteers for a number of positions!

If you want to be a part of the solution in making AMSAT operational and work toward designing, building and finding a launch, WE NEED YOU!

No pay for 5+ hours per week, but a great deal of satisfaction in knowing you are helping make something happen.

We need people with these skills:

- Marketing
- Sales
- Software engineering
- Hardware engineering
- PC based software design
- Web design and maintenance
- Project management
- Documentation
- Hardware testing
- Software testing
- Hardware prototyping
- Specific area Web site information maintenance
- Video recording, digital conversion and editing
- Write technical or instructional material
- Educational activities
- Promoting AMSAT as an Area Coordinator



and any other area you think you think you can make a difference.

We often have people volunteer, but many don't deliver on their promises. So, pick an area that you think needs improvement and explain what you will do to make it better. Then do something to show that you can follow through.

Send your suggestions, actions plans and a description of why you are capable of doing this task to Gould Smith, WA4SXM, wa4sxm@amsat.org



Education Paradigm Shift for AMSAT to Support Subsidized Launch Opportunities

by Mark Spencer, WA8SME, mspencer@arrl.org

(When this article was originally written, Mark was the ARRL Education and Technology Program Director. Though he is now engaged in a new position working on R&D of unmanned, underwater and low visibility sea vessels, he still supports the ARRL's education mission as time and proclivity permit. Bringing space technology directly into the classroom remains his passion.)

Abstract

Subsidized launch opportunities for satellites come with some hefty strings attached. To qualify for a subsidized launch the satellite must meet a moving target of criteria that supports DoD, industry, education, and/or humanitarian relief interests. AMSAT can qualify for subsidized launch opportunities without making significant changes in the goals and mission of the organization or the proposed satellite capabilities. AMSAT only has to re-tool and re-package the organization's education theme to make it more visible and viable to the launch providers. This paper emphasizes a growing gap of unmet needs along the education continuum that are not being addressed by the satellite community. Then suggestions are presented how AMSAT, in cooperation with other Amateur Radio related interests, can address those needs and in turn leverage those efforts to qualify for subsidized rides into space.

Some Background

To put the following thoughts in context, let's take a moment to reflect on education. One paradigm used to model education is a four-tiered pyramid. (Figure 1) The base of the pyramid is Inspiration: to affect, guide, or arouse interest. The next level is Engagement: to obtain and hold attention. The meat of the pyramid is the third level, Education: to provide or facilitate gaining knowledge and training. The ultimate goal of education is reflected in the top of the pyramid, Employ: to put the knowledge gained through education to some use or service. The education pyramid represents a life-long activity that enriches lives.

The reason why we need to revisit education in the most fundamental terms is because it is through education that AMSAT will have the greatest chance to qualify for subsidized launch opportunities.

Opportunities

Recently, launch vehicle operators have offered subsidized satellite launch opportunities for the bargain price of approximately \$40K, which is basically the cost of the satellite integration into the launch vehicle ... the actual ride into space is free. Of course there are restrictions. The satellites must conform to a standardized size and mass, multiples of the CubeSat standard of 1U equal to a 10 centimeter cube and up to 1 kilogram in mass. The purpose or mission of the satellite also needs to conform to the interests of the supporting organization to include, but not necessarily limited to Department of Defense, industry, education, and most recently humanitarian relief interests. Within these interest areas, research in space weather and advanced technologies are just two that might gain the attention of some launch providers. However, it is doubtful that the AMSAT community shares those interests nor has the capability and/or resources to devote to space weather research or develop new and innovative advanced technologies on a grand scale (though the talent is certainly there, only bounded by fiscal realities, shallow pockets and proclivity). The most likely areas of interest that AMSAT could address to qualify for a subsidized launch

opportunity are in the areas of education and perhaps humanitarian relief.

Some Shortfalls

If we look at how the satellite community is currently addressing the needs posed by the education pyramid, there clearly are some good things that are being accomplished and probably under-advertised and appreciated. But there are also some unmet needs that can be addressed. The point of this paper is to point out that if AMSAT were to do a better job of "chest beating" concerning those pyramid tiers that we are currently addressing and make some minor shifts in our satellite efforts to address some of the unmet education needs, then perhaps we can leverage a revised education mission into subsidized rides into space.

The CubeSat community, primarily graduate level educational institutions, are doing some phenomenal, cutting edge things to advance space-borne technology. However, in my view, though the CubeSat community talks a good game of addressing broad educational interests, they are more program and institution focused and tend to favor post graduate students to prepare them for employment in industry. This is not a criticism, they are serving the needs of their universities and students, but they are in reality not providing very much support

below the graduate level, and certainly not supporting students at the high school level and below. Criticism of this over generalization is certainly warranted however, but an objective review would prove this generalization to be pretty accurate. The danger here is that if the lower level students are not introduced to satellites and space-borne technology early in their education careers and encouraged to pursue studies in the technology, where will the future graduate students come from?

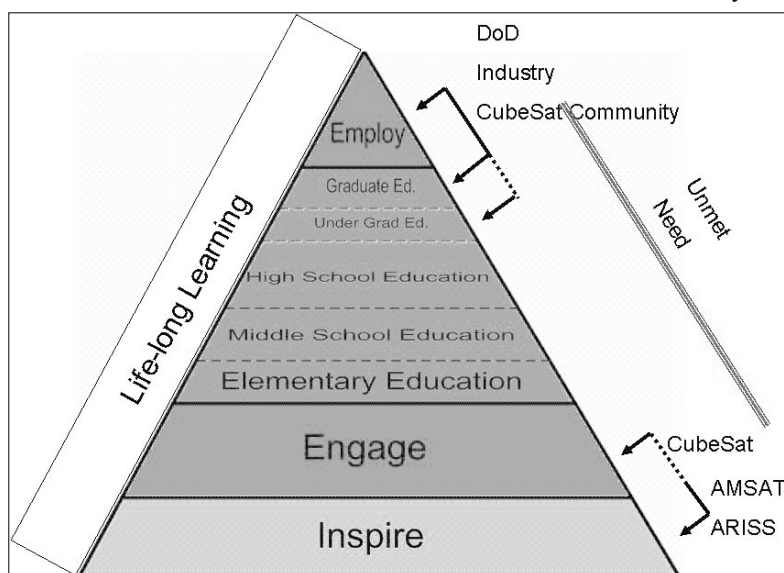


Figure 1



On the other end of the continuum are the AMSAT and ARISS communities. ARISS until very recently has focused on inspiration. This is evident in their program focus on dedicated school contacts that are measured as successful by the number of questions asked of the astronauts. The majority of the contacts are conducted by telebridge, with the ham radio element on the other side of the globe connected to the student audience via speakerphone. This is a reality of the operational constraints of the ISS mission schedule. The result is that students are insulated from the technology required to connect with the astronauts, all they see is that there is a wizard behind the magic curtain and voices coming out of the speakerphone. There is little focus on teacher and/or student preparation before the ARISS contact and little if any follow-up after the contact. Again, criticism of this over generalization is certainly warranted, and there are shining examples of success after the inspiration of the ARISS contact, but those successes truly are rare and rarely substantive beyond the immediate media hype aftermath.

What AMSAT is Doing

The AMSAT community also contributes significantly to inspiration though primarily to the lifelong learners that make up the ham radio operator audience. Satellite demonstrations at hamfests and school science fairs are indeed very inspirational and have some educational value.

Where AMSAT differs from the ARISS and the CubeSat communities is in regard to supporting the educational pyramid at the tier of engagement. Once a student is inspired to look further into the study of space-borne technology, they need ample opportunities to “do” satellites, not just “witness” satellites. This requires that students can engage, to use, satellites in space on a regular basis in support of their school curriculum and private interests. The CubeSat community currently supports engagement by sending telemetry from their systems in a format and using frequencies that are within reach of a modest ground station operated with some modest skill (however this support is at risk which will be addressed later). Though ARISS has recently added engagement to their mission statement portfolio, they have not followed up the statement with actionable signal activity. Once the initial 7-minute ARISS contact is made, the ad-hoc contact opportunities with the

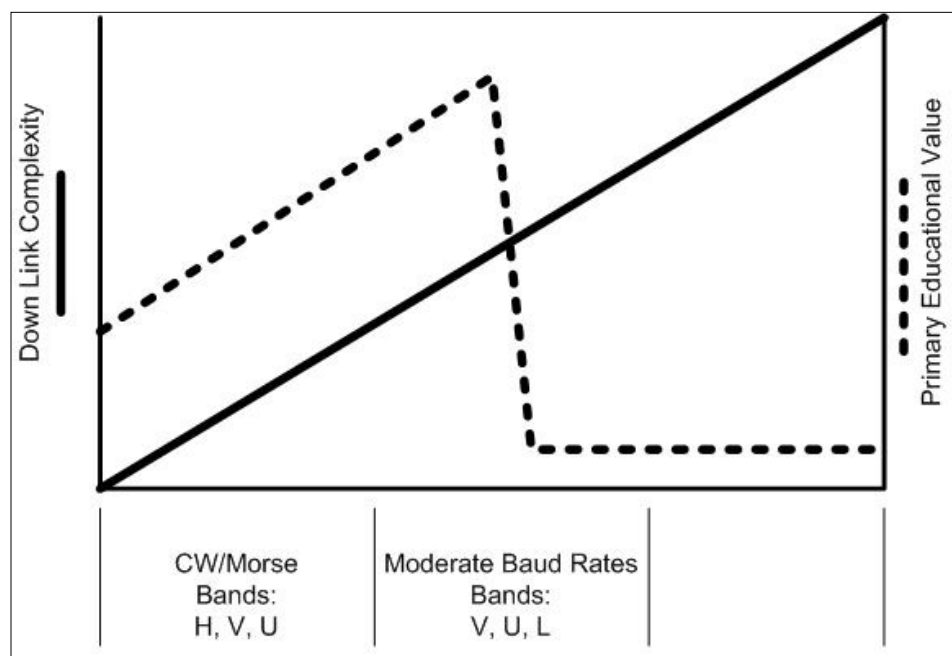


Figure 2

astronauts in orbit are becoming increasingly scarce, and when they are available, they are unpredictable. Other ISS-based radio systems such as the cross band repeater, the APRS digipeater, or the SSTV transmissions are also rarely heard and are also random. True engagement involves access, ARISS signals and contact opportunities, for whatever reason, fall short of providing engagement opportunities that are usable in today's classroom. On the other hand, AMSAT assets, along with the assets of the other amateur satellite organizations across the globe ‘do’ engagement...engagement is the fundamental purpose of these satellites. The problem is that we do not package the engagement mission using the educational vocabulary needed to articulate that mission to those outside our tight knit community.

Some Missed Opportunities

Returning for a moment to the CubeSat community's engagement activities, telemetry from the portfolio of CubeSats is transmitted primarily on the U band and using Morse code or sometimes packet radio. This makes access to these signals with a modest investment in ground station equipment and modest operator skill possible (though it can be argued that the number of people fluent enough in Morse code is dwindling). However, as the CubeSat community pushes the envelope, which is the natural thing to do as technology advances are being made, this push also starts to erode away the easy and ready access to the telemetry being sent from the satellites, in other words, limits the

engagement potential of the systems. The graphics shown in Figures 2 & 3 illustrate the trends and consequences of the trends that I see the CubeSat community taking.

The left axis represents the increased complexity of the down link signals sending telemetry. The right axis represents the continuum of educational value, cost of the ground station equipment or system vulnerability as appropriate. The horizontal axis represents the continuum of the capabilities of the ground station needed to receive and exploit the telemetry, with rightward movement representing increasing costs.

As the on-board sensors advance, more data is collected which requires high baud rates and therefore higher frequencies to accommodate the higher data rates resulting in an increase in down link complexity and an increase in ground station costs (the solid line). Likewise, as the satellite capabilities advance, the educational value of those systems also increases up to a point as represented in the dashed line. There is a point at which the downlink signals are so complex that they require ground stations that are so complex and expensive that schools cannot afford the equipment for the limited number of signals and by default because they cannot afford to access and exploit the signals, the educational utility drops.

This results in a Catch 22 situation for the CubeSat community and makes their more advanced systems actually more vulnerable

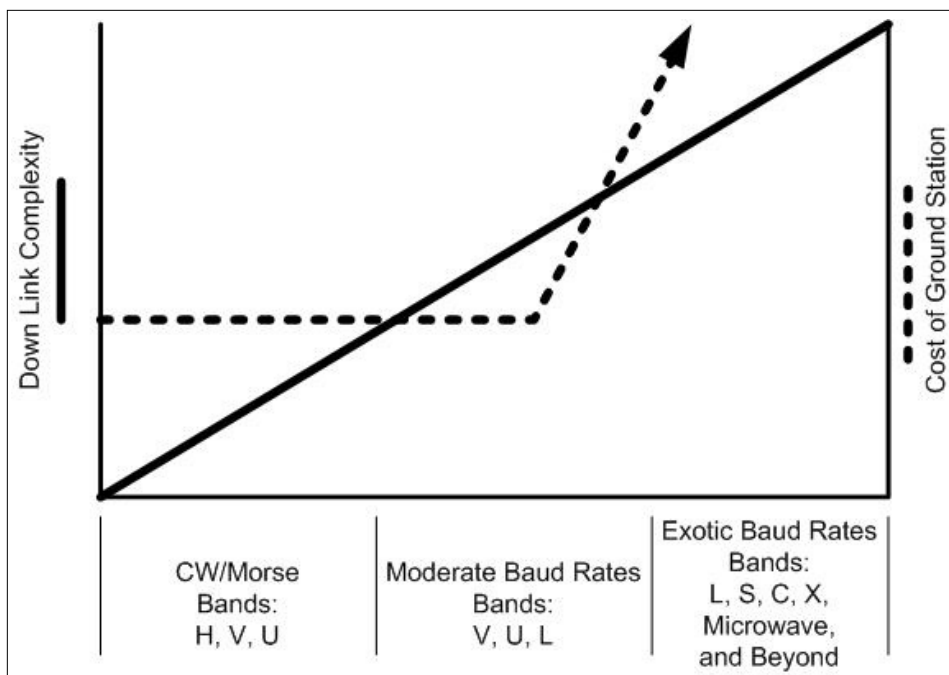


Figure 3

to data loss and disruptions. As mentioned, as the data link complexity increases, the station complexity increases and the number of stations available to collect the data goes down. As the number of ground stations capable of collecting the data decreases, the data rates to down-load the collected data needs to increase so that the data can be accessed by the few remaining stations within range of the satellites during the short time available, which leads to pressure to increase data link complexity to accommodate for the lack of ground station availability ... and the cycle continues. I heard an example of this situation recently during a conference presentation. The presenter lamented that there were only five stations globally capable of receiving a particular satellite's whole orbit collection because of the amount of data collected, the low orbit and therefore short time in range of the ground stations.

The system was vulnerable because a loss of just one station results in significant loss of data collection. The proposed solution was to increase baud rates and down link frequencies (which arguably would further limit the number of stations capable of receiving the downlink and also further restricting access by potentially interested schools and students).

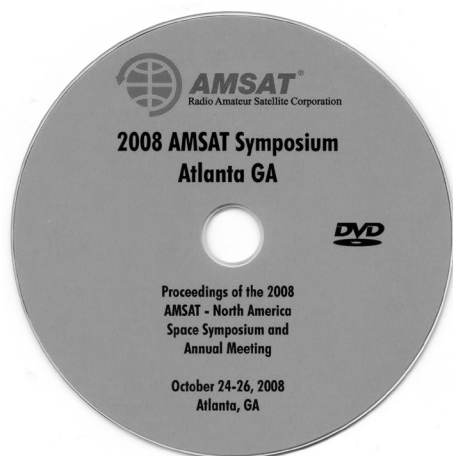
Need to Re-focus

The answer to me at least is clear. While the CubeSat community continues to push the envelop of technology, they should keep in mind that there is a need to support the basic education community that needs engaging signals from space so that they use these signals to educate their students. So while the trend to increased downlink complexity will continue, capabilities must be built into future satellite systems to provide accesses to the telemetry with affordable

and achievable ground station equipment. And while the CubeSat community supports this engagement effort, at the same time they are building some redundancy into their collection system so that one failure of a system node is not catastrophic. I guess the question that needs to be answered is does it make better sense to have just a handful of ground stations capable of receiving the telemetry transmitted at cutting edge rates, or have thousands of stations capable of receiving portions of the collected data transmitted at more modest rates but shared via the Internet? Additionally, is it better for 5 institutions of higher learning alone be active participants in the system, or is it better for potentially thousands of education institutes from all grade levels as well and interested private citizens outside the formal education community be actively engaged in the system? I actually feel that we can have both.

Resources Alone are not Sufficient

There is one more piece of this puzzle that is not being addressed by the satellite community; teacher education. Teachers teach the way they were taught. Despite the movement toward teaching to specific educational standards and benchmarks, teachers tend to teach what they are most comfortable teaching. The problem is that teachers have not been taught about satellite technology, nor is it likely that they have been taught how to teach satellites. There are of course those rare student teachers, but the majority of the college students who pursue studies in satellite technology in all likelihood will not go into teaching. What this means is that while the satellite community addresses the education pyramid and tries to support the four tiers of the pyramid, there also has to be a concerted and parallel effort to "train the trainers" in satellite technology.



2008 Proceedings DVD's are available. Contact the AMSAT Office.

A DVD for the 2008 Symposium is available.

It has the presentations, audio files and papers.

Dan Schultz's Banquet Talk on The Hubble Space Telescope Repair Mission - slides and audio

Phil Hartman's Introduction to DSP Workshop - slides and audio plus

2004 Symposium papers

2005 Symposium papers

2007 Symposium papers



This train the trainers effort needs to be on two fronts, one within the universities' teacher training programs, and the other an outreach in-service training program for teachers already in the classroom.

Way Forward and Up!

Okay, so what? What does all this have to do with competing for subsidized rides into space for our satellites? Here are a few things that I wish the AMSAT community would consider.

We are already doing engagement, it is just that we don't know it, and we certainly do not stress this to the other members of the satellite community to our benefit. Because we are already deeply involved in engagement, we can take a leading role in attempting to influence the rest of the satellite community to better support bringing space borne technology education into our schools. If AMSAT is recognized as the primary source of engaging space borne resources, that puts our applications for subsidized launch opportunities in a better context during the review processes that are allocating these launch grants. So now, how do we start?

First and foremost, we need to start with the fundamentals. Space borne technology has become an integral part of the fabric of our culture. If you look around where you are sitting, there are probably a number of things that depend on space borne technology and there are many activities that you do throughout your day that also depend on satellites. If satellites and space borne technology are so important to our culture, maybe the average citizen should learn more about it ... the average citizen should have some level of space literacy. To start, AMSAT should define what space literacy is, "what does the average citizen need to know about space and space borne technology to be productive citizens of this country, and to use that technology to enrich their lives." The definition of space literacy then becomes the compass for follow-on activities.

Second, based on the definition of space literacy, AMSAT should develop plans for our future satellites that support space literacy. That is not as difficult or as limiting as it first might appear. The AMSAT community has focus groups of enthusiasts that are promoting systems that meet their literacy (interest) needs whether it is HEO, LEO, FM, analog, digital or whatever birds, they all make up the overall concept of our vision of space literacy. But, and this is a big caveat, the planning for future systems needs to also be based on current (and projected) realities. Subsidized launch opportunities are most likely to be LEO orbits with an inclination that may not be ideal ... in other words; you take what you can get. Also, launch opportunities will probably not be made available years in advance, more likely they will be made available to those organizations that have "shovel ready" satellites that are ready to go when the launch is scheduled. [Nice analogy to the current vernacular! – Ed.] This will probably dictate systems that have more generic capabilities, less specialized or cutting edge and inexpensive enough to be built and shelved ready to go.

Third, continue to support education and advancement of satellites among the Amateur Radio community but double dip that effort by leading the way in developing a standardized, affordable and capable ground station to access satellites. If the amateur satellite community is fluent in the acquisition, set up and operation of a standardized ground station, then there will be thousands of trained trainers that can assist others, and local schools and teachers to set up stations in their institutes and gain access to satellites.

Fourth, the proliferation of a standardized ground stations might encourage the CubeSat community to dumb down their data links (a poor choice of words, but reflecting the intended meaning) to allow more accesses to the signals and encourage more students

outside the immediate project audience, and radio amateurs to participant and support the system's telemetry collection effort while making their system less vulnerable to single point failures.

Fifth, if the standardized ground stations are readily available, easily replicated and are affordable, perhaps more teachers will be encouraged to integrate space technologies into their curriculum. This will generate the need for teacher training. While AMSAT cannot expect to run a teacher in-service training effort, the AMSAT community certainly can support other teacher in-service training efforts such as the ARRL's Education and Technology Program Teachers Institutes. The grant programs can provide the resources for teacher training as well as the procurement of the ground station equipment making space in the classroom very affordable for schools. Grantors however will not throw money at good intentions. There has to be a reasonable expectation of success and return on their investment. Trained and supported teachers leading a school program initiative go a long way in showing potential of success. AMSAT members can provide invaluable support to their local schools by mentoring teachers and school programs and provide some traction where the granted monies, resources, and training meet the road. This kind of support provides some depth to a school program that grantors can appreciate.

And finally, if AMSAT were to pursue these five efforts, the educational mission of AMSAT will have expanded from the obvious Inspiration tier alone to include the Engagement tier that we have already been doing unobtrusively, and delve deeply and head-on into supporting the Education tier. These credentials would then have some substance and specifics that lend themselves to develop a very competitive application for a subsidized launch. 🌐



OSCAR-1 - A Part of History

The Project OSCAR folks are celebrating the 50th anniversary of OSCAR-1.

Back in 1961 the Project OSCAR newsletters were very short and dealt with only one subject. Each newsletter is a few paragraphs long and each is just about OSCAR 1.

Don Ferguson, KD6IRE, forwarded a series of Project OSCAR newsletters that were hand typed back in 1961. There are many files, but each is only a page long. Included here are some of the very first OSCAR-1 news releases from 1961. Thanks Don!

In addition, ANS will include these notices in future ANS Bulletins. ANS will send a plain text version of each of the original OSCAR-1 news items close to the dates from 50 years ago. There will be several installments covering the launch that began it all. 🌐

First News Release, November 15, 1961 at 1345 PST

U. S. RADIO AMATEURS TO LAUNCH "PIGGY-BACK" SATELLITE

SUNNYVALE, CALIF. -- A hitch-hiking radio transmitter that will speak to thousands of amateur radio operators throughout the world is scheduled to be launched into space orbit next month, announced the American Radio Relay League.

Weighing only 10 pounds, the satellite has been designed, built and tested by a group of California (Peninsula) radio amateurs organized as the Project Oscar Association of the League.

"OSCAR" stands for Orbital Satellite Carrying Amateur Radio.

The radio "ham's" transmitter beacon will be carried into space aboard a scheduled space vehicle and will radiate signals in a world-wide amateur frequency band of 2-meters, radio amateur M. C. Towns, Jr. (Saratoga, Calif.) announced today.

Transportation into space will be provided by an Air Force vehicle to be launched from Vandenburg Air Force Base, Calif.

Once in orbit, the Air Force vehicle will "kick away" the piggy-back radio amateur satellite, leaving it to follow its own course around the earth. The mother satellite will then continue to perform the experiments for which it was intended.

Radio Amateur Towns, the Oscar Association Chairman, stressed that Project Oscar "is a serious, civilian, non-commercial effort to obtain information from outer space, and to introduce radio amateurs and lay scientists to new concepts in outer space communication.

"This miniature radio transmitter will be tracked and observed by radio amateurs and all interested observers throughout the world.

"It will serve to instruct the radio amateur in the art of observing and tracking a moving space object. In addition, the mass of data gained from world-wide observations will provide information unobtainable by any other means.

"There are an estimated 300,000 licensed radio amateurs in the world, and the American Radio Relay League hopes a large number of these hobbyists will participate in the forthcoming experiments."

Towns noted that the radio amateur has, in the past, been a pioneer in various fields of radio communication, and that hundreds of U. S. radio amateurs are now engaged in space research and other space activity.

The 10-pound Oscar satellite consists of a low-power beacon transmitter contained in a rectangular metal casing about a foot long. It will send out a continuous Morse code signal of the letters H-I, four dots followed by two dots.

Later satellites proposed to be built by the Oscar Association may both receive and transmit amateur signals.

- more -

-2-

As soon as this transmitter is in orbit, notification will be flashed to radio amateurs throughout the world by the American Radio Relay League, the international organization of radio amateurs which is sponsoring and cooperating in the project.

"Radio propagation, Heaviside layer refraction, antenna efficiency and other data can be gathered and correlated from thousands of points over the world's surface," Towns said.

"The cause of good will," Towns continued, "will be served in that radio amateurs, located in virtually every country of the world, would have a common amateur interest in observing and tracking their own satellite, and in exchanging scientific information relative to improved equipment for receiving the satellite signals."

The Oscar transmitter is designed to operate on a frequency of 145 megacycles and can be heard by home experimenters having simple receiving equipment, Towns said.

"Cooperation in the forthcoming tests is invited from any interested party," the Oscar Chairman stated, pointing out that support has already been contributed by the Air Force and numerous private concerns interested in furthering communication knowledge, and entirely on a no-cost basis of lending a helping hand to the amateurs in their own project.

The radio amateur satellite idea originated in 1959 with a Los Angeles amateur operator, Don Stoner, who suggested that radio amateurs had the technical know-how to build their own satellite if someone only had the vehicle to carry it into space.

He, along with radio amateur Fred Hicks, of Campbell, California, and other radio "hams" kept the idea alive and formed the Project Oscar Association. The idea spread among radio clubs of the Los Angeles and San Francisco area and gathered support from radio amateurs nation-wide, including the radio amateur organization, the American Radio Relay League.

Radio "ham" Nicholas K. Marshall, technical director of the Oscar program, noted that the soon-to-be-launched satellite is but a first step in the overall Oscar concept.

"Later satellites to be built by the Oscar group will perhaps receive and transmit amateur test signals for specific space experiments," he said

Marshall noted that there are approximately 12,000 radio amateurs in the Soviet Union, and that the Oscar Association hopes to receive tracking data from some of them also.

#

continued next page ...



OSCAR NEWSLETTER

December 1, 1961

Good News!

The following is quoted from the Department of Defense News Release dated November 15, 1961:

AIR FORCE TO ORBIT SMALL SATELLITE FOR "HAM" OPERATORS' USE

"The Air Force is planning to boost into orbit a small amateur radio satellite so that "ham" operators around the world can contribute to the world's knowledge on the development and operation of space communications systems.

"Known as Project OSCAR -- Orbiting Satellite Carrying Amateur Radio -- the program is the result of extensive thought and planning on the part of several California amateur operators. They have formed the OSCAR Association to follow through on the project.

"The Air Force Space Systems Division in Los Angeles has agreed to orbit the OSCAR satellite on a space available basis on board a DISCOVERER satellite which will be launched from Vandenberg AFB next month.

"The OSCAR satellite will weigh approximately ten pounds and will be lifted into orbit on the external aft portion of the AGENA Satellite. Sometime after the AGENA has attained orbit the OSCAR satellite will separate from the mother vehicle. Antennae will extend and the transmitter will commence operation.

"The OSCAR satellite will contain its own battery power system and is anticipated to have a 30-day life in orbit.

"The OSCAR satellite is designed to investigate radio propagation phenomena in the two meter (144-146) portion of the radio frequency spectrum."

Simultaneously, a letter from Dr. J. V. Charyk, Under Secretary of the Air Force to the American Radio Relay League, says (in part):

"I am pleased to advise that the Air Force will undertake to place into orbit an Oscar package....Our Space Systems Division has been instructed to accomplish the Oscar package launching at the earliest feasible date (italics ours) on a non-interference basis to the performance or mission of the launch carrier vehicle.... Please be assured of the complete cooperation by the Air Force toward successful accomplishment of this amateur experiment."

THIS MEANS THAT THE LAUNCH INTO SPACE OF OSCAR I, THE WORLD'S FIRST AMATEUR RADIO SATELLITE IS IMMINENT -- PROBABLY WELL WITHIN THE MONTH! ACTUAL LAUNCH DATE CANNOT BE YET RELEASED FOR SECURITY REASONS. LISTEN TO THE VOICE OF AMERICA BROADCASTS AND THE OFFICIAL ARRL BROADCAST FROM WIAW FOR LAUNCH DATE! ALSO WATCH YOUR LOCAL NEWSPAPER FOR LAUNCH INFORMATION!

RECENT "UP" AND "AP" OSCAR NEWS DESPATCHES HAVE BEEN FEATURED IN MAJOR NEWSPAPERS, AND IN ADDITION, W6SAI AND K6LFH WERE INTERVIEWED BY VOICE OF AMERICA ON THE

-2-

NOVEMBER 27TH AMATEUR RADIO PROGRAM WHICH FEATURED THE OSCAR STORY.

YOUR COOPERATION IN THIS IMPORTANT, WORLD-WIDE AMATEUR SPACE EXPERIMENT IS URGENTLY REQUIRED. SEE RECENT ISSUES OF QST AND CQ MAGAZINES FOR ARTICLES ON RECEPTION AND TRACKING OF THE OSCAR 145 MC RADIO BEACON. AS THE BEACON HAS NO RECEPTION FACILITIES, DO NOT MAKE CALLS TO THE BEACON. KEEP YOUR TRANSMITTER CLEAR OF 145 MC! OSCAR I WILL BE IN POLAR ORBIT, THUS PASSING OVER EACH POINT ON EARTH APPROXIMATELY FOUR TIMES PER DAY ON NORTH-TO-SOUTH AND SOUTH-TO-NORTH ORBITS.

THE TIME IS NOW! ARE YOU READY?

NOW THAT WE HAVE RECEIVED ALL NECESSARY PERMISSION AND ASSISTANCE, OSCAR I WILL BE ON ITS OWN WHEN IT IS EJECTED FROM THE PARENT VEHICLE. THE OSCAR ASSOCIATION AND THE U. S. AIR FORCE HAVE AT THIS POINT DONE ALL THEY CAN DO TO MAKE THE EXPERIMENT A SUCCESSFUL ONE. THE RESULTS OF THIS EXPERIMENT WILL DEPEND UPON YOU - THE RADIO AMATEUR. YOU MUST CARRY ON FROM THIS POINT! YOUR COOPERATION IN THIS NON-COMMERCIAL, NON-MILITARY SPACE EFFORT WILL BE IN THE BEST TRADITIONS OF AMATEUR RADIO! GOOD LUCK!

All reception reports of Oscar I should be directed to:

Oscar Association, P. O. Box 183, Sunnyvale, California, USA.

All correct reports will receive a special OSCAR I QSL card, verifying reception of the world's first amateur radio satellite.

continued next page ...



December 12, 1961

OSCAR SATELLITE IN ORBIT

OSCAR SATELLITE IN ORBIT

OSCAR SATELLITE IN ORBIT

At 2041 GMT, 12 December 1961 the Oscar satellite was hurled into orbit by the Discoverer XXXVI launching vehicle from Vandenberg Air Force Base, California. The satellite immediately went into a North-South orbit and was picked up loud and clear by the hams at KC4USB (Marie Byrd Base) at the South Pole a few minutes after launch. The word was quickly relayed back to the Oscar Tracking Station, K6QEZ, by W4ABY. Acquisition was also obtained by hams at Kodiak, Alaska and by KH6UK in Hawaii on the first pass. Oscar is on a frequency between 144.990 and 145.008 and has tremendous c.w. signal strength on a direct, overhead pass! Tracking reports have begun to flow into the Center. WIAW heard the first pass S-9 over the East coast. The following telegram was received by the Center from the RSGB: OSCAR HEARD 0055 GMT X KEYING OK X STRENGTH NINE PLUS X DOPPLER SEVEN KC X FURTHER DATA AIR MAIL X.

Orbit is being computed, but insufficient time has elapsed to permit predictions to be made of time Oscar will pass over your area. Listen to WIAW and the Voice of America for orbital predictions. Continuous 24-hour a day monitoring is essential until predictions are established. In fact, this monitoring is urged to check for unpredicted reception at times when the Oscar satellite is theoretically out of range! Our thanks to the Air Force and men of Vandenberg AFB who helped to make this historic milestone possible! Actual launch was attended by W6SAI, K6LFH, W6MLZ and W6TSN. Full Oscar story in February QST and CQ and more details in our next news letter!

LISTEN TO OSCAR! SEND ALL REPORTS TO
PROJECT OSCAR, BOX 183, SUNNYVALE,
CALIFORNIA, U.S.A.

December 21, 1961

As of December 19, 1961 (one week in orbit) the amateur radio satellite Oscar I had completed 104 revolutions about the earth on a North-South-North orbit. Reports are beginning to pour into the Oscar Headquarters. A total of 296 reports from 11 foreign countries have been received, with radio messages indicating more are on the way. Mail has been delayed because of the Christmas rush, but it is hoped that future reports will reach us more rapidly. Reports have proven to be consistent and accurate enough for use in generating tracking predictions. Telemetry information provided by the keying rate indicates that Oscar I is running a fever. Recent data establishes the temperature of the package to be 125°F.

The following is a summary of the Oscar I satellite:

Frequency: Approximately 144.983 Mc. Power Output: 100+ milliwatts
HI-rate: Proportional to temperature. (10 HI's in 30 seconds = 64°F).
Tumble rate: Approximately 20 seconds.
Apogee: (Point farthest from the earth) - Approximately 275 miles.
Perigee: (Point closest to the earth) - Approximately 150 miles.
Orbital Period: Approximately 92 minutes. Total Doppler Shift: Approximately 6.5 kc.
(Frequency received is higher than transmitted when satellite is approaching your station; lower when going away).
Transmitter: Transistor crystal oscillator on 72.5 mc., transistor amplifier and "Veri-cap" diode doubler to 145 mc. Keyer consists of transistor multi-vibrator and counters with diode logic. Oscillator is keyed in base circuit.
Power Supply: Mercury batteries. Expected life of batteries: 3 to 4 weeks.
Antenna: 1/4-wave monopole, about 19 inches long. Dimensions and weight: 12" x 10" x 8". Weight: 10 pounds.
All daytime passes are from North to South: All nighttime passes are from South to North.

A preliminary review of a sample of reports for one pass provides some interesting information. The acquisition times and fade-out times correlate closely among all the receiving stations in the same area. Further, the correlations have improved noticeably for the later orbital passes. This emphasizes that operators are gaining experience and that the predictions have been sufficiently accurate to permit early acquisition. Many amateurs have been surprised at the great range which may be spanned by this beacon, whose output power is about 1/4 that required to light a flash-light bulb. Reports indicate reliable reception up to a distance of about 1400 miles from the satellite path. On an overhead pass, signal reports of 40 decibels above noise level are common!

- 2 -

The Oscar Data Reduction group has reported a few messages indicating that the last dot of the letter "I" has been missing. Anybody noticing this who has a tape recording of the "missing dot" is requested to air mail it to the Association as soon as possible.

Reports of the "HI" rate are urgently requested. If the temperature inside the package continues to rise, it is possible that the operating life of Oscar could be cut short by a high temperature failure of some component. The temperature rise does not seem linear, so all reports will be welcome! Also, please monitor the frequency in off-hours to determine if Oscar can be heard by unusual propagation modes at great distances! Orbital data is being broadcast by WIAW (see QST for schedules) and by the Voice of America "Space-Warn" program on various frequencies (9.525, 11.79, 11.83, and 15.29 mc) at 0330 GMT, Monday through Saturday.

Send all reception reports of Oscar to: Project Oscar Association,
Box 183, Sunnyvale, California, U.S.A.

Thanks for your splendid cooperation and keep up the good work! 73.

Bill
W6SAI



The perfect combo, without compromise.

HF/6m/2m/70cm/23cm¹ Transceiver

IC-9100

For years, the attention to receiver design focused on the HF bands, leaving the upper bands a bit neglected. Icom changed the ham world with the introduction of the IC-7800, which incorporated a new front-end design just for 6m. Now, Icom introduces the IC-9100, extending the latest in front-end technology up to more of the VHF/UHF bands. 2m, 70cm, and 23cm¹ enthusiasts can now benefit from high-end IF-DSP performance too!



100/100/100/75/10¹ Watt Output²

AM, FM, SSB, RTTY, CW, & DV¹

Satellite (Mode B/J/L¹)

Independent Receivers

3kHz/6kHz 1st IF "Roofing" Filters¹ (HF/6m)

Two Independent 32-bit IF-DSP Systems

Double Conversion Superheterodyne
with Image Rejection Mixer (HF/6m/2m/70cm)

Type B USB for Rig Control and Audio



Shown with optional desktop microphone SM-30 and additional third party accessories. ¹Optional unit required. ²See manual for AM output power.
©2011 Icom America Inc. The Icom logo is a registered trademark of Icom Inc. 30618

ICOM